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ABSTRACT

This volume presents ten papers by authors from diverse academic disciplines that challenge the acceptance of dominant patterns of knowledge in the present educational and social climate and suggest that our creativity, our capacity to comprehend complex phenomena, and the future well-being of out society depend on our willingness to embrace new patterns of knowledge. Following an introductory essay by Richard Bjornson and Marilyn Waldman, the papers are as follows: "A New Logic of Human Studies" by Frederick Turner; "Nonlinear Science and the Unfolding of a New Intellectual Vision" by Alan Beyerchen; "Beyond the Transmission of Knowledge: A Vygotskian Perspective on Creativity" by Vera John-Steiner; "Creativity as a Distributed Function" by Bruce West and Jonas Salk; "A Systems Overview of the University and Society" by Howard T. Odum; "The University and the Animal That Learns" by Paul Colinvaux; "The Wo/Man Scientist: Issues of Sex and Gender in the Pursuit of Science" by Evelyn Fox Keller; "How Can a Humanist Compare Religious Classics?" by Wendy O'Flaherty; "Creativity and the University--A View from the Piano" by Sharon Mann-Polk, and "The Faces in the Wall" by Kate Wilhelm. (JB)

RETHINKING PATTERNS OF KNOWLEDGE

Edited by
Richard Bjornson
Marilyn Waldman

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Rethinking Patterns of Knowledge

Richard Bjornson
and
Marilyn R. Waldman

editors

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Introduction

Richard Bjornson and Marilyn Waldman

The contributors to this volume come from a variety of disciplinary backgrounds ranging from medical research, mathematics, and environmental engineering through zoology and psychology to history, literature, religious studies, and the performing arts.[1] Yet they all share a common concern. The dominant patterns of knowledge in the present educational and social climate are based on linear thinking, rationalistic analysis, and the quest for generalizable simplicity. Under such circumstances, individual success generally results from the competency with which these patterns of knowledge are mastered and then utilized to bring about expected or predictable outcomes. Alternative views of reality, whether they originate within our culture or outside of it, tend to be resisted or rejected out of hand. Each contributor to the volume challenges the unquestioning acceptance of these patterns and suggests that our creativity, our capacity to comprehend complex phenomena, and even the future well-being of our society depend upon our willingness to embrace new patterns of knowledge and not allow ourselves to be defined solely in terms of what has been taught in the past.

As Alan Beyerchen points out, much of our everyday discourse reflects a "common sense" understanding of scientific laws. In today's world, these laws presuppose a faith in the principle of linear causality, the belief in a value-neutral perspective from which truth can be defined, a conviction that the material outcome of an undertaking is the primary reason for engaging in it, and the assumption that problems can be solved by breaking them down into smaller problems and subjecting each subproblem to independent rational analysis. Such beliefs and assumptions promoted the industrial revolution and produced a vast explosion of knowledge, but despite their

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usefulness they might be granting us insight into a miniscule corner of reality at the expense of blinding us to all the rest.

Many scientists are aware that linear mathematical models do not accurately describe complex feedback phenomena, and even computer graphic representations of static scenes appear more realistic when they are generated on the basis of nonlinear coordinates. The explanatory power of ecological systems thinking, chaos theory, and non-linear mathematics are changing the ground rules of scientific inquiry, and Beyerchen concludes that they would provide a richer, more accurate image of reality if the principles behind them were expanded into other fields, including the common sense approach to the problems of everyday living.

Frederick Turner believes that human society offers a superb illustration of these principles in action. According to him, the view that human behavior is causally determined by natural laws and cultural conditioning processes is inadequate insofar as it obscures the discontinuity and reflexive complexity that characterize human life. As individuals interact with others and respond to feedback generated by their own behavior, they become involved in ever-changing social patterns that can be modelled but not predicted. Like a Mandelbrot set or the action of a Shakespeare play, these patterns can only be known through experience, and since the self-governing processes that bring them into being produce an order to which we, having been shaped by the same processes, naturally respond, Turner argues that our own aesthetic instincts are the best guides to a better understanding of ourselves and our world.

The survival of the human race could depend upon our ability to assimilate new ways of seeing the world, for as Bruce West and Jonas Salk suggest, the creative thinking necessary to overcome pressing environmental and social problems might well mirror neurobiological structures that can only be properly understood from a holistic, non-linear perspective. When regarded in evolutionary terms, they explain, the human race operates like a complex system in which there are sudden, disproportionate changes that cannot be predicted on the basis of initial conditions. Although the behavior of such systems is unpredictable, it is not random, for it inscribes the same sorts of patterns that Turner and Beyerchen mention -- patterns that must be experienced or modelled while they are taking place in order to discover their outcomes. Since most of nature functions in this non-linear fashion, West and Salk conclude that it would be a tragic mistake to persist in defining it solely in terms of positivistic, cause-and-effect analysis.

An awareness of complexity and unpredictability leads to a recognition of the need for new ways of visualizing and modelling reality. Turner refers to the patterns generated by non-linear phenomena as paisleys and suggests we can know them by appealing to our aesthetic sense or by reenacting them. Beyerchen calls attention to the enormous potential for using images to store

and communicate information about these patterns. Ever since Plato, visual intelligence (or "imagizing") has been subordinated to rational understanding, even though the human mind can grasp more information more quickly in images than in verbal form. Beyerchen argues that this neglect of pictorial literacy has inhibited rather than facilitated the comprehension of complex wholes. If the next generation is to understand and appreciate them, the children of today must be accorded the opportunity to perceive reality from these new perspectives.

Although Howard T. Odum's approach is more quantitative than that of Turner, he too is concerned with the complex functioning of whole systems. In the contemporary world, societies are constantly facing choices about the optimal use of the resources available to them, and Odum has developed a method for helping them make such choices in a rational way. To gauge the energy efficiency of alternative courses of action, he devised a standard measure called emergy (embodied energy). Calculated in solar (or coal or petroleum) emjoules, it can be used to determine the amount of energy that is needed to produce a given commodity or service. If the outputs of any social enterprise are not proportionate to emergy inputs, that enterprise will eventually be abandoned, for the longer it is retained, the more its energy deficit will jeopardize the long-run stability of society. Odum's emergy survey of the University of Florida illustrates how an awareness of systems connectivity can reveal the true social value of stored information and help us make choices that are in our own long-term self-interest.

Paul Colinvaux also looks at the university as part of a larger system, but his principal concern is with the limits placed on learning by patterns of behavior that have been etched in human consciousness by the evolutionary process. He points out that continuity of behavior through many generations is characteristic of most animals because a successful way of adapting to a particular environmental niche has survival value and will tend to replicate itself as long as it continues to be successful. Unlike most animals, however, human beings have learned to change their niche without dividing into new species. This flexibility has enabled us to override genetically programmed behavior patterns and to expand into a wide variety of habitats throughout the world.

Yet even this flexibility has limits, according to Colinvaux, because learning beyond what is necessary for successful adaptation to a given niche would inhibit an individual's survival chances by provoking him or her to experiment with new behaviors, most of which will be inadaptive. As a result, natural selection has conditioned human beings to learn well during childhood and to resist new learning once they have reached adulthood. Since college students are nearly adult, Colinvaux contends that most of them have already internalized their guiding beliefs and assumptions by the time they enter college. If what Colinvaux claims is true, the major challenge

confronting higher education today is the need to counteract such behavior patterns and to stimulate the sort of creative thinking that may be necessary for our survival.

Viewing all of humanity as a whole system in which every element influences every other element, West and Salk argue that this sort of creativity is a distributed function: that is to say, individual instances of creative behavior reflect the functioning, at a given point in space and time, of a worldwide system of interrelated phenomena and do not (as many people believe) result from a determinate chain of local conditions. As in the systems described by Turner and Beyerchen, the emergence of creative thought cannot be predicted, but it can be either fostered or suppressed when it does appear.

This is precisely the point at which the comments of Vera John-Steiner, Sharon Mann-Polk, and Kate Wilhelm become relevant. According to John-Steiner, schools focus primarily on the transmission of the known so that novices can be transformed into participating adult members of their culture. However, creative accomplishment, discovery, and new knowledge depend upon a type of thinking that is seldom encouraged in the schools because it is more ambiguous and complex than "normal thinking." Incapable of being taught in the usual way, this type of thinking derives from specific kinds of interactions with a larger system.

As Mann-Polk testifies on the basis of her own development into a concert pianist, the first step in this process usually involves a crystallizing experience that plunges an individual into an intense preoccupation with a specific area of his or her culture. There is almost always a strong identification with a mentor who may be a teacher or an influence from the past. During this stage, the individual engages in what Mann-Polk calls "work/play," absorbing the mentor's skills and vision by emulating them. But the truly creative individual most go beyond imitation, and John-Steiner explains that the recognition of this need often results in a crisis when previously competent performance begins to break down. Mann-Polk describes how she experienced such a crisis in her first year at the conservatory while working on a Bach Prelude and Fugue. Unsatisfied with her competent performance of the pieces, she cloistered herself for several weeks in a dark room, playing and replaying these pieces in different ways until her countless interactions with them allowed her to hear them in a new way.

Often the flash of creative insight occurs when the individual relaxes after a period of concentrated effort that assures an intimate familiarity with all the materials relevant to the problem he or she has been struggling over. In this moment of relaxation, an unexpected juxtaposition is made, suggesting a precedent for looking at the problem in a new way. Such insights are more likely to occur in people who have been exposed to a variety of disciplines

and perspectives. But even more important, creative individuals must have the self-confidence to break with "normal" approaches to the problem. They would not be capable of new insight if they had not studied the problem intensely, but they must also allow their intuition to carry them beyond disciplined imitation. Within the context of the world view being proposed by Turner, Beyerchen, Salk, and West, this reliance on intuition is what puts individuals in contact with the complex ambiguity that characterizes themselves and the world around them.

But if, as Mann-Polk and Wilhelm suggest, creative intuition is a serious form of play, the impulse toward it is constantly being stifled in educational institutions where standard ways of seeing and doing are indiscriminately imposed on people. Wilhelm tells several anecdotes about children who were punished or humiliated for having sought to express their own visions of reality in art or literature. Creative intuitions probe the boundaries established by society, and because society and its schools are always trying to preserve these boundaries, many of these children were "cured" back to normalcy and probably cut off forever from what John-Steiner calls "discovery thinking." Wilhelm's own conceptualization of a novel or a short story hardly conforms to the linear processes that are taught in writing courses; on the contrary, it involves precisely the sort of intuition and holistic imagizing that Beyerchen and Turner discuss in their essays.

The multiperspectivalism that fosters creativity also invites people to recognize that every conception of truth exists within a cultural context that frames it and gives it meaning. Wendy O'Flaherty makes this point when she argues for the teaching of non-Western myths and literary classics in American schools and colleges. In contrast to recent educational critics like William Bennett and Allan Bloom, she feels that Western classics can no longer serve as a source of cultural values with which all educated people ought to identify. By their very nature, these works are archaic and based on assumptions that few people in the contemporary world would accept. In fact, such texts generally sanctioned the values of a small elite class that regarded itself as the measure of all humanity, and in today's society only a select few are truly familiar with them. In the United States, O'Flaherty argues, Dick Tracy and "Dallas" come closer to providing a common denominator of cultural reference than do Shakespeare's plays and the *Iliad*.

What is important in these classics is important because it is true, but as O'Flaherty points out, once the validity of such a statement has been acknowledged, we have to admit that the myths and classics of non-Western cultures might also be true. If this is actually the case, it behooves us to "possess" the truth in these non-Western narratives by translating their "otherness" into our own contemporary idiom. Such an exercise would, according to O'Flaherty, have distinct advantages for us. It would enable us to reappropriate the classics of the Western tradition by showing us how to

approach them in such a way that they could once again become meaningful to us. By allowing us to perceive the familiar in a foreign setting, these non-Western texts also permit us to see ourselves mirrored in them, but from a vantage point we never could have attained if we had refused to go beyond the canon of Western classics. The reward for adopting a cross-cultural perspective is therefore a richer, fuller picture of reality and a better understanding of ourselves.

A similar conclusion is suggested by Evelyn Fox Keller, who proposes that we reexamine the social and cultural assumptions behind the practice of science, particularly in relation to gender. She herself believes that much of what has generally been defined as science is actually a reflection of male behavioral norms. For example, tests that supposedly measure mathematical aptitude have consistently recorded higher scores for male than for female children, but Keller points out that these results show no correlation with creative mathematical thinking. What they do seem to measure are the types of mental behavior that are conditioned into male children at a very young age. Attempts to achieve parity between men and women in the practice of science by denying gender differences have therefore been singularly unsuccessful.

In Keller's opinion, the only solution to this problem is to acknowledge gender differences and to welcome a variety of perspectives, including those commonly identified with women, into the practice of science. At present, a majority of American scientists are middle-class white males. By training and selection, they are predisposed to adopt a relatively small number of theoretical models that are considered most likely to produce results; however, the belated recognition of women scientists like Earbara McClintock demonstrates the inadequacy of this system. Because McClintock asked different questions of her data and employed unorthodox methodologies while focusing on the relationship between the observer and the observed, her research program allowed for the possibility of genetic transposition, and she was able to find it. If she had restricted her observations in conformity with the most likely models of genetic behavior, her brilliant discoveries might never have been made.

Nearly all the contributors to this volume recognize that the creative process entails intuitive leaps that transcend analytical, linear thinking. Colinvaux describes this process in terms of people's ability to alter their own behavior by overriding previously learned or genetically programmed instructions. Turner refers to human nature as a grammar that people must learn to use with skill and aesthetic sensitivity. Opening ourselves to relational, process-oriented thinking will not cut us off from the truth, as our society's conventional wisdom suggests. In fact, these new patterns of knowledge give us access to forms of truth that will enable us to entertain a richer, more fully dimensioned image of the world.

For example, Keller points out that women in our society are socialized to think in relational terms. If certain kinds of problems prove intractable when viewed from perspectives characteristic of the dominant socio-cultural group in the scientific community, it makes sense to support research conducted on the basis of different perspectives, including those that tend to be held by women. The ultimate reward for maintaining a diversity of ideas and interests in the scientific community would be a greater awareness of complexity, ambiguity, and interconnectedness.

As Odum, Salk, West, and others contend, this awareness may well be a prerequisite for the long-term survival of human society. Having reflected upon the self-destructive tendencies unleashed by modern industrialized society, Odum advocates an ethic of equitable symbiosis as opposed to consumerism and competitive individualism. In the course of study he proposes for the university of the future, students would acquire not only verbal and quantitative skills but also the capacity to think in global terms of process, systems connectivity, synthesis, and interdisciplinarity. From a slightly different perspective, Salk and West argue that the only way to encounter the self-destructive tendencies of contemporary society is to foster creative thinking among people who have a profound respect for the subtle web of interdependencies in which all life is embedded.

The contributors to this volume are posing some of the same questions that philosophers have been raising for centuries, but the opportunity to combine new scientific perspectives with the insights of human experience has created new possibilities for obtaining satisfactory answers to these questions and for bridging the gap that separates science from the liberal arts in the Western world. By linking non-linear mathematical models with intuitive human activity, Beyerchen and Turner are suggesting that the aesthetic and the true may be coterminous in a world of complex ambiguity, and by examining many cases of discovery thinking, John-Steiner shows that intense interaction with this complex ambiguity may be the source of creativity as well as its greatest reward. There will always be a tension between people's inclination to preserve existing patterns of knowledge and their desire for innovation. When this tension erupts in dialogue, a rethinking of commonly accepted assumptions becomes possible, and all the contributors to this volume have vigorously challenged us to participate in such an enterprise.

Notes

[1]They all participated in a conference on "The Educated Citizen and the University of the Future" at The Ohio State University in May 1987. The papers collected here reflect the presentations and comments that were made in a somewhat different form during this conference.

A New Logic of Human Studies

Frederick Turner

Consider the following paradoxes. A welfare system designed by well-meaning politicians guided by the advice of the wisest sociologists and economists available, costing billions of dollars, whose net effect is radically to increase the numbers of the poor, especially women and children, and to deepen their misery, incapacity, and despair. A stock market which rises because the statistical instruments designed to detect similarities with previous rises are causing investors to make it rise in the same pattern; and which helps to generate the financial conditions it predicts. A social polity expressly created to ensure the equality of all citizens, which produces an archipelago of concentration camps across a continent; and whose theoretical dismissal of the concrete effectuality of theorizing unleashes real social forces of unparalleled savagery. A foreign policy which depends for its effectiveness on the fact that the government does not know it is being carried out. An economy which attracts foreign investment by borrowing so much money that it is able to remain politically stable and thus economically healthy.

More and more of our collective life seems now to be populated with such logical monsters, such scyllas and charybdises of reflexion and feedback. Yet, good as well as evil can be compounded by the peculiar kind of interest which they offer; unfairly, unto him who has much, much shall be given, and the kingdom of heaven is like a mustard seed: something that will grow quite unpredictably all over the place.

But these monstrosities are the despair of any "scientific" sociology or historiography. And now physics itself seems to have caught the plague; and even that purest sanctum of linear logic, mathematics. Those positive knowledges to which modernist history and sociology appealed for a model now seem almost as messy and chaotic as the seething life of human culture. This new vision of the "positive sciences" has emerged from the brilliant

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new studies of chaotic, nondeterministic, recursive, fractal, dissipative, catastrophic, period-doubling, and feedback-governed systems, associated with the names of Mitchell Feigenbaum, Ilya Prigogine, Benoit Mandelbrot and René Thom. Perhaps some of these terms require a brief (and necessarily incomplete) explanation. An algorithm is a mathematical method for doing something -- say, generating a geometrical shape in a computer graphic. A *recursive* algorithm is one which possesses an internal loop, such that the solution arrived at by one passage through the loop is fed back again into the beginning of the loop, "adding," as Benoit Mandelbrot puts it, "fresh detail to what has been drawn on previous runs." Mandelbrot gave the name *fractals* to a family of shapes, irregular and fragmented surfaces, curves, and "dusts," generated by recursive algorithms based on a random or arbitrary numerical "seed," which repeat their own form or type of form at different scales of magnification, so as to pack into their details at one scale a microcosm of the next larger scale. The space-filling curves of Piano are only one example. Mandelbrot sees these forms everywhere in Nature; in trees, cloudscapes, coastlines, the bronchi of the lungs, corals, star clusters, waves, craters, and so on. A dissipative system is one which maintains its form not despite its tendency to decay but by means of it. Dissipative systems can be self-organizing; I shall discuss some examples later, such as certain forms of turbulence. The term is Prigogine's. A *catastrophe* is a discontinuity, as when the gradual increase of some factor suddenly crosses a threshold in which some entirely different state is precipitated; it can be observed when a cooling supersaturated solution suddenly crystallizes, or when an animal's behavior suddenly changes during a gradual change in the stress it is undergoing, or when a gradual change in economic factors triggers a massive move in the stock market index. In his catastrophe graphs, Rene Thom was for the first time able to describe such discontinuities or catastrophes mathematically. *Period doubling* -- Feigenbaum's term -- is what happens when certain ordered systems break up into chaotic ones, like a smoke-ring dissolving in the air; out of such chaotic situations, however, new forms of order can arise spontaneously, given the right circumstances.

The lawfulness governing such systems is of a radically different kind from the rules that govern classical deterministic systems, and that are embodied in the empirical causal logic of the modern scholarly humanistic disciplines. In other words, if even the sciences themselves no longer insist on a causal mechanism for events (and its attendant rules of objective and positivistic empirical evidence), then it is high time the social, historical, and humane studies reevaluated their scholarly methods. The indeterminacy of quantum physics was hard enough for the academy to swallow. The new indeterminacy is of quite a different kind.

What the new science shows us is that the operation of fairly simple processes -- the period-doubling mechanism of turbulence, for instance, or the random walk of particles precipitating to a crystal -- can very rapidly

bring about states of a system that are utterly unpredictable from their initial conditions. In a computer simulation of planetary orbits, for instance, there is an unstable zone in which the velocity and proximity of a satellite with respect to its primary is critical to whether it will settle into a stable orbit, whether it will escape altogether, or whether it will adopt an eccentric, continually changing looping orbit around its primary. Each time the initial velocity or position is defined to a further decimal place, the resultant orbit is radically different -- not different so as to form a convergent series homing in on an asymptote, but utterly and unpredictably different. Thus, the accuracy by which the world is defined makes a total difference to the nature of the world itself. A seacoast measured with a one-mile ruler might be hundreds of miles long; if measured by a foot-ruler, thousands; if by a micron ruler, millions; and each level of magnitude has its own lawfulness and predicts its own pattern of wave action as the surf rolls in.

Given their unpredictability, one might expect such processes to bring about mere chaos, mere ugly inchoateness. But no. Often enough they resolve themselves into extremely beautiful, complex, and stable structures, to which I shall give the generic term "paisleys." Such forms are coming to replace the classical shapes of ideal geometry -- lines, triangles, circles, regular solids -- as the governing imagery of the scientific visual imagination. Examples range from the convection-cells of a good rolling boil in a teakettle or the planetary pattern of trade winds or Jupiter's Great Red Spot -- a storm that has raged for hundreds of years -- to the forms of electrical discharge, crystals, river drainage systems, and organic structures. These systems forget their causes, and indeed, if their causal determination were the only language in which they could be understood, they would be inherently unintelligible. The "modelling" or "generative" logic by which they *are* now understood is profoundly new as mathematical formalism, but, as I hope to show, very ancient as an intuitive human activity.

The test of whether we truly understand such a system is no longer our ability to predict it, but our ability to construct another system that does the same sort of thing as the original. Perhaps we could say that we still test by prediction, but what we are predicting is not a certain future state of the system, but the general type of behavior of the whole system itself. In other words, we are not predicting along a line of time, but across a sort of plane. And this notion, of other temporal geometries than the linear, has enormous implications not only for the study of history, but for the arts and humanities in general.

The common feature in all these systems is feedback. The simplest forms of feedback are given in the initial conditions, for instance, the setting of the thermostat of a home heating furnace. In this case the only unpredictable element is the precise value of some parameter -- in our example, the temperature of the house at a specific time, in the course of its wanderings up

and down around the "attractor" or average temperature we have set for it. More complex feedback systems can set their own parameters, or even create the sort of parameters toward which they aspire or around which they oscillate. That is, their state at any given moment is the resultant of ordering processes that have arisen within the system itself.

Now the supreme example of such self-organizing systems is life. And we may go further and say that the evolution of life has been the evolution of more and more autonomous and complex and unpredictable -- because inventive -- feedback systems. The human species is, as far as we know, the most advanced state of this process, where it shows in its most paradigmatic and articulated form the general tendency it always exhibited. Nature strives toward freedom, in the sense of autonomy, as the clearest expression of its essence. And here of course we return to our subject, which is the present crisis in history and social studies.

For surely, *a fortiori*, the collective activities of human beings are of all phenomena in the world the most fully governed by the principles of complex feedback systems. Social game theory takes us part of the way. Consider a simple dyadic predicting contest; a little marital spat on a Sunday in some large American city. There is tension between Jack and Jill; they haven't been able to talk much recently, because they have both been working hard. Jack, as usual, intends to get Sunday lunch. Jill, however, knowing what Jack has in mind, intends to shop for lunch at the deli instead in order to upset him. But, Jack knows his Jill. Guessing that she intends to go out to the deli in order to forestall Jack's usual lunch, Jack plans to claim that he is feeling ill and doesn't want lunch. Jill, though, expects the "I feel sick" ploy, and finds occasion to joke pleasantly about Jack's past propensity to use pretended illness to get out of things. Jack, recognizing that the game has got too complex at this level, changes levels by deliberately randomizing his own behavior. He starts a tedious conversation about fatal illnesses. Jill is flummoxed only for a moment, then recognizes the paradigm- or genre-switch. She plays the same game, but without any pretense at normal conversation, breaking in with some earnest remarks about chickadee nesting habits. She has thus thematized the issue of avoiding the subject and changed the ground rules once again. Jack now steps outside of the conversation and looks at it as a stranger might; no longer as "Jack versus Jill" but as "Jack and Jill versus the outside world." He sees how absurd they sound, catches Jill's eye, and they both collapse in laughter. No doubt they will go out to lunch at their favorite cafe. Or maybe not.

Jack and Jill have become a "we" by internally modelling each other's motivations and each other's image of the other. In the process they have touched on a broad and sensitive range of values and value judgments. Their story is not atypical; the narrative and dramatic arts are full of this sort of thing, and Erving Goffman and Thomas Scheff, among others, have provided [illegible]e analyses of it. Now imagine it extended to the billions of dyadic

relationships in the human world, and the trillions of larger group relationships. Nor are such strategies unique to intimate relationships. One could easily demonstrate the same sort of strategy at work between, say, two opposing generals in the wars of the Austrian Succession. All human interactions significantly involve such halls of mirrors.

Our first observation, that it was an error to apply to human affairs the deterministic logic of classical science, would, if left on its own, imply that we might as well give up on such studies altogether. But there is now a body of theory and concept that can put them on a new footing. In the remarks that follow I shall pay special attention to historical and social studies, but I do so to let a part stand for whole; much of what I have to say applies broadly to the humanities, the academic study of the arts, and the human sciences as well.

For want of a nail, the kingdom was lost. Imagine the predicament of a historian, reminded, by some trivial historical episode with momentous effects, of the insecurity of the discipline of history. The tiniest event can snowball into the most gigantic consequences, just as the minutest subatomic difference in a flow can result in an utterly altered pattern of turbulence. Philosophers of history have never been able to demonstrate that this snowball effect *cannot* take place. Perhaps every event that occurs is just as crucial, and just as insignificant, because undifferentiated in importance from everything else. Perhaps this is the spectre, the existential cackle of empty laughter, that haunts certain historians, that drives them to construct their elaborate deterministic edifices of economic and social history, class struggle, invisible oppressors, conspiracy theories. Like Casaubon in *Middlemarch*, they set out to uncover the Key To All The Mythologies.

Another kind of historian with a different temperament, confronted with the appalling indifference of historical significance, will seek to enumerate all the primary sources, to recite all the "facts", to deal with all exceptions to all rules, all special cases, all the statistics, and to do it without bias, without giving any one fact more significance than any other. It is as if one should seek an understanding of a turbulent flow by listing and mapping all the positions of all the particles in the flow at all times. Perhaps if the map is on a fine enough scale, the answer will emerge. The mapmakers of Borges' mad dictator who made a map of the country so perfect that when opened it covered the country itself and brought on its economic ruin, or the mole in Kafka's story who kept building new tunnels to keep watch on the entrances of his burrow, are literary examples of the mindset. Such heroic historians, fixated on the old intellectual modes, accumulate a tragically meaningless scholarship. Given this approach, why should not a life of scholarship which devoted itself to a descriptive catalog of every spot on the library wall -- and there are enough spots on any library wall, if we choose small enough parameters -- why should not such a labor be just as valid as Darwin's

collection of evidence for evolution, or Albert Lord's for oral composition? Why is one fact more significant than another?

Not unlike the collecting moles in their theory, but different from them in practice, are those postmodernists and deconstructionists who accept the complexity and interdependence of the world, but refuse to recognize the real stable order that it also generates. Unable to escape their own Oedipal and patriarchal model of knowledge, which insists that the identity of something derives from what originated it, they regard order as an illusion because that order originated out of chaos. Self-made men and women, they are as horrified by the idea of the self-made -- by the *made* -- as by the primal scene itself. For them to make, to create, is a fascist imposition of a totalizing structure upon the freeplay of the world. They thus abolish the idea of the writer, the maker, the text, the made thing, even the reader, even the world. They seize on quantum theory as a sort of warrant for a deconstructed and valueless universe -- quite erroneously, of course, as indeterminate particles happily clump together to make very determinate pieces of matter. Those determinate pieces of matter indeed evolved sometimes into self-ordering and even free systems; but this does not help the deconstructionists' case.

If the responses of the historical determinists, the obsessive collectors, and the rebels without a cause are inadequate to the problem of history, what approach might really work? The beginnings of an answer to this question are what this essay proposes; to get there we must follow a somewhat winding path of dialectical reasoning.

Any analysis of historical events that we make, or any theory of social behavior we formulate, is itself one of the determining factors in the situation it describes. Thus, there is no "meta" position, no detached Olympian viewpoint from which objective assessments can be made; and therefore no escape from the apparent chaos of mutual feedback. We are all revolutionaries and reactionaries, whatever our claims as historians or social scientists. Economists are just another group of competitors over what constitutes value.

Not that this struggle for ontological control is a blind one. We would be totally ineffective at it if we were not able to assess the motives and assume the world view of others. And even this would not be enough. Our imaginative model of the other must contain its own image of ourselves -- the gift, said Robert Burns, is to see ourselves as others see us; and that image itself must contain its own assessment of the other. And our outer negotiations take place not just between our own persons but also among the entire *dramatis personae* of the inner drama by which we estimate the future. The confusion is not one of blindness, but of too much sight; not of randomness, but an excess of determinants; not of chaos, but of an order too complex to be explained before the next complicating event comes along -- of [illegible]ich the next complicating event *is* the best explanation.

Indeed, this capacity to impose our interpretations on things is not only

our predicament but also what enabled us to second-guess, predict, and control the simpler systems of nature, such as the biological, chemical, and physical ones. We bought our power over the rest of nature with the essential uncontrollability of human events. We can control nature to the extent that we stay one step of reflexivity ahead of it. Nor is even nature innocent, but itself the resultant and living history of a cosmic evolution which pitted many forms of reflection against each other; the marvelous cooperation of nature is a prudent and subtle form of mutual feedback. Even so, when we find we can reduce another organism to a successfully testable set of laws and predictions, it is a sign that we are dealing with a lower order of reflection than our own.

Thus, to attempt to do so with human beings, to educe and apply the laws governing them and to predict their actions is, in human terms, a viciously aggressive act, an attempt to get control at the expense of others' freedom. It implicitly reduces human beings to the level of things, of lower animals. But this indeed is what much social and economic history, much sociology and progressive political theory, has attempted to do. The promise such studies held out was not lost on those with the sweet thirst for power. Transformed into political programs those systems appeared in our century as the great totalizing regimes -- Marxism, Fascism, National Socialism, International Socialism. We should not be surprised at the vigorous counter-reaction of human cultures against such systems.

In the light of this analysis it now becomes clear why, with the best will in the world, all principled revolutions have ended up diminishing human variety and freedom in their societies. For a revolution to be truly freeing it must be unprincipled, in the sense that its intentions do not rest on a predictive theory of human social behavior. Such a revolution was the American, whose ideas, enshrined in the Constitution, really amount to a declaration of regulated intellectual anarchy. The principle of separation of powers, which is, more than equality and more even than democracy, the central message of the Constitution and the thematic undertone of every article, is an intuitive recognition of the reflexive, self-organizing, unpredictable, feedback nature of history, which by reinterpreting its initial conditions is able to forget them.

Separation of powers makes politics into a drama, not a sermon. Perhaps the true hidden presence behind the Constitution is William Shakespeare.

All the world's a stage. We are all actors, in both senses of the word. Our inherent value derives from that condition, not from Kant's notion that we are ends in ourselves. We can still keep our dignity even if we are, for immediate purposes, means, as long as we are actors in the drama. Even if their function is to serve, the crusty boatman or witty nurse or pushy saleslady are interpreting the world from their own center, are characters, *dramatis personae*, to be ignored by others at their peril; and are thus free. We might,

parenthetically, therefore view with alarm the tendency in modern and postmodern theater to get rid of characters altogether.

But of course, even *this* formulation which I have made is itself a part of the situation it describes; it is a speech in the play, to be evaluated by your own reflexive processes of assessment. Let us see whether the line of thought it prompts is a more or less freeing one than its competitors.

We immediately run up against a large problem. Does this critique of historical and human studies mean that they must revert to the status of chronicle and appreciative observation? Like amateur naturalists, must their practitioners only be collectors, without testable hypotheses or laws? Should we just admire the exquisite coiled turbulence of human events, wonder, and move on? The French historian Fernand Braudel is almost such a historical naturalist; there are moments as one contemplates his great colorful slowly roiling paisley of Mediterranean history, seemingly without direction or progress, that one could wish for little more out of history. Should not the historian be a sort of Giacomo Casanova, a picaro among the courts and sewers of eternal Europe or China, remarking the choice beauties to be seen on one's travels?

A directionless view of history can be seductive. But even if the essential logic of the modern humane disciplines is utterly erroneous, it has nevertheless provided an impetus and direction for research, and has led to the vigorous discovery of huge masses of information, at least some of which is interesting to everyone. The bias of that information, the preponderance of certain types of source and the direction of the researchers' gaze, may be corrupting; but in itself we feel it to be valuable.

But let us explore the possible value of the naturalist's or chronicler's agnosticism. Although it might not wish to own up to it, the deconstructionism actually presents a rather good case for this perspective; to the extent that a case as such, with all its theoretical baggage, can be made for so uncaselike an approach. Deconstruction is purposely not long on logic, and as such it is quite consistent. The *bete noire* of all deconstructionists is totalization. What does totalization mean? Once we have disposed of those cases of totalization which every sane person would deplore -- Nazism, for example -- we get into interesting territory. What makes deconstruction unique is its inability to distinguish between those forms of order we would all agree are evil, and such things as the narrative structure of a text, marriage and family, the idea of the writer and the reader, even the very idea of the self or person. There is no plausible place for deconstructionists to stop on their slide into total inarticulacy. Poor Jacques Derrida, nailed recently to the wall by the inspectors of ideological purity on the subject of South Africa, was forced to squirm to reconcile the indifference of his skepticism toward all forms of order, his fundamental belief in the radical apartheid of all points of view, and his decent liberal distaste for the regime.

Certainly History and Sociology would be easy meat for a

deconstructionist's acid test; but so would any human or indeed natural product, process, or action. Deconstructionism has now begun to turn its acids on itself; as it does so, it will encounter the paradox of what container to keep the perfect corrosive in. And if it is not the perfect corrosive, deconstruction must end up, like its old enemy Descartes, asserting with more totalizing violence than any other system that one idea which is not subject to the deconstructive process: in Descartes' system, the *cogito ergo sum*, "I think, therefore I am," isolated by his skepticism about all else; in Derrida's, that force or energy he perceives as prior to and underlying all difference.

But there is a rather benign face to deconstructionism, to be found for instance in Jean-François Lyotard's classic essay on postmodernism. Here he offers a way of thinking about human society that makes no generalizations and which recognizes all human activities and thoughts as flows in a great interacting soup of information. On the face of it, a very attractive vision; and it satisfies some of the criticisms we leveled earlier at History and the social "sciences."

But in doing so it abdicates that very activity -- holistic understanding and the enrichment of the world by interpretation -- that characterizes the human *Umwelt*, the human species-world, itself. The admonition not to totalize is the most totalitarian command of all, since it essentially dehumanizes history. The feedback process of human culture is a feedback *of* what deconstructionists would call totalizations. The open-endedness of history is created by the competition and accomodation of various candidates for the last word, the *dernier cri*, the formula of closure (including this one); it is an ecology of absolutisms. Nor is this ecology a random play of flows, without direction or growth; technology, records, and enduring works of art constitute ratchets which prevent any return to earlier, less complex states of the system, just as genetic inheritance did in earlier ages. Thus, history is an evolutionary system, with the three factors required for evolution to take place: variation (provided by the unpredictable paisley of reflexive events), selection (provided by the competition and accomodation of "totalizations"), and inheritance, a conservative ratchet to prevent what is of advantage from being lost.

The only way open is to seek principles of understanding and descriptive categories that are proper to our own level of reflexive complexity. To do this is essentially an artistic, a constructive, a performative, a religious activity, and it cannot fully depend on the capacity for calculation by which we claim to understand the rest of the natural world. (Even this claim must yield at a certain point. Ultimately, scientists appeal to the beauty of a theory to justify it before the infinite plenum of its equally consistent rivals.) History is an art, even a technology, even a liturgy, as much as it is a science; and it is so not only in the activity of historiography, but also in that of research.

In other words, I am proposing a change in our fundamental paradigm of historical and human study. And here another set of major scientific advances comes into play. Most workers in the historical and sociological fields still accept the cultural determinism that was one of the first naive responses of the West to the cultural diversity of the newly-discovered non-western world. Thus, for them the units of historical study, human beings, are *tabulae rasae*, blank sheets to be inscribed by cultural conditioning or economic pressures.

More recently, however, in fields as diverse as cultural anthropology, linguistics, twin-studies, paleoanthropology, human evolution, psychophysics, performance studies, neuroanatomy, neurochemistry, folklore and mythology, and ethology, it is becoming clear that we human beings bring to history and society an enormously rich set of innate capacities, tendencies, and exclusive potentials. We uncannily choose, again and again, the same kinds of poetic meters, kinship classifications, calendars, myths, funerals, stories, decorative patterns, musical scales, performance traditions, rituals, food-preparation concepts, grammars, and symbolisms. We are not natureless. Indeed, our natures include, genetically, much of the cultural experience of our species in that period of one to five million years of nature-culture overlap during which our biological evolution had not ceased, while our cultural evolution had already begun: the period in which unwittingly we domesticated and bred ourselves into our humanity. The shape and chemistry of our brains is in part a cultural artifact. We are deeply written and inscribed already, we have our own characters, so to speak, when we come from the womb.

So, having taken away one kind of rationality from historical and human studies, we may be able to replace it with another. But in so doing, are we not committing the very sin, of reducing a self-organizing and unpredictable order to a set of deterministic laws, of which we accuse the determinist historians? Are we not replacing cultural or economic determinism with biological determinism? Not at all. First, to understand the principles governing the individual elements of a complex system is, as we have seen, not sufficient to be able to educe laws to predict the behavior of the whole ensemble. The beautiful paisleys of atmospheric turbulence are not explained by the most precise understanding of the individual properties -- atomic weight, chemical structure, specific heat, and so on -- of its elements. Second, the peculiar understanding of the human being that we are coming to is of a creature programmed rather rigidly and in certain specific ways to do something which is totally open-ended -- that is, to learn and to create. Our hardwiring -- whose proper development we neglect in our education at great peril -- is designed to make us infinitely inventive. Our nature is a grammar that we must learn to use correctly, and which, if we do, makes us linguistically into protean gods, able to say anything in the world or out of it.

Thus, the paradigm change which this line of argument suggests is from one in which a social universe of natureless, culturally determined units is

governed by a set of causal laws which, given precise input, will generate accurate predictions; to one in which a cultural universe of complex-natured but knowable individuals, by the interaction and feedback of their intentions, generates an ever-changing social pattern or paisley, which can be modelled, but not predicted. The meaning of understanding would change from being able to give a discursive or mathematical account of something to being able to set up a working model that can do the same sorts of things as the original.

Fundamental political concepts like freedom, war, civil order, equality, literacy, power, justice, sovereignty, and so on would no longer be defined in terms of a set of objective abstract conditions but as living activities in a one-way unrepeatable process of historical change. It would be such a revaluation as occurred in literary criticism in the nineteenth century, when tragedy came to be defined as a process, an organic and recognizable activity, rather than as conforming to such rules as the "three unities." Conceivably the automobile has done as much to create political freedom as any set of laws; yet historical and political scholarship is taken by surprise by such relationships. Imagine how governable the Soviet Union would be if everyone had a car -- or a personal computer, with a modem; *glasnost* may be more than what the Party bargained for. Is not justice very much a matter of talent and personality? Blake said: one law for the ox and the lion is oppression. Might there not have been more equality of certain valid kinds between a gentleman and his valet than between an employer and employee in a classless society? Is not power the most questionable and fugitive of all concepts, seemingly so solid at one moment, but blown away by unpopularity the next? What is war in an age of terrorism, export dumping, military computer games, and nuclear standoff?

Such questions are not intended to induce the *aporia*, the bewilderment, of the mole-historian we depicted earlier, trying to define those troublesome ideas by the mere accumulation of data, so as to take into account all the exceptions; rather, they are a preface to a new/old kind of historical understanding. Objective and abstract definitions of political concepts imply utopias, ideal social states towards which historical polities should strive; satisfy the definitions, and we have perfection, the end of history, an objective rationality to judge all of the past! Horrible idea; but it governs most political enthusiasm. Instead, let us imagine a peculiar kind of progress; not the old one, towards Whig empire or Hegelian state or proletarian or socialist or technological paradise: but a progress in changing terms which themselves progress by subsuming earlier ones; a progress that looks like decline or stagnation to those fixed to one idea of it; a progress not along a straight time-line but along one which curves back and fills up the holes in itself until it begins to look like a plane or a solid; a progress forged out of the evolutionary competition of totalizations, in which those most accomodating, most loving to each other, like the mammals, have the best

chance of survival.

But is not progress an outdated concept? Even among the historians of science there are now those who deny any progress. Thomas Kuhn, the theorist of scientific revolutions, has publicly questioned whether there can be any improvement from one scientific paradigm to the next -- say, from the Aristotelian to the Newtonian. Fritjof Capra goes even further into scientific agnosticism. The deconstructionists all vehemently deny the possibility of progress. Likewise Robert Heilbroner and the Club of Rome. But all these thinkers are caught in a logical trap, from which there is no escape. For either their own ideas are an improvement on those of their predecessors, in which case progress has occurred (and could in theory occur again), or they are no improvement, which implies there is no reason for us to take them seriously. In either case their ideas do not stand outside or above the process of history.

Since some notion of progress is thus a logical precondition of any attempt at understanding or argument, let us examine where the critics of progress go wrong. Kuhn argues that since the criteria of coherence and explanation that Aristotle's science satisfied are different from the criteria met by Newton, to compare the two systems is to compare apples and oranges. Since the differences between the criteria themselves is a matter of values, not facts, no determination of superiority can be made between them. The assumption is that values are not real; and since this assumption is the key to an argument whose conclusion -- there can be no progress -- is manifestly self-contradictory, this assumption must be false. Values, then, are real. Their improvement can improve the criteria of scientific study, and thus the quality of scientific knowledge.

And here we may be in a position to begin to redeem that promise, of principles of understanding and descriptive categories proper to our own level of reflexive complexity, that we implied earlier. The real forces at work on the stage of history are *values*. And values are uniquely qualified for a role both as tools to understand history and as forces at work in it. One qualification is just that: they straddle the worlds of action and knowledge, they admit candidly our involvement, our partisanship, our partiality and our power. Objectivity in a historian is an impossible goal in any case. Another qualification of values is that they give a kind of direction to history, the possibility of progress, which as we have seen is the logical precondition of any inquiry. Values are essentially dynamic, readjusting, contested, vigorous, as the word's derivation from the Latin for "health," and its cognate "valor" imply.

We must reexamine those older partisan brands of historiography that wore their values on their sleeves: heroic, exemplary, mythic history. Perhaps their intellectual credentials were not as shaky as we thought; perhaps they were not so naively unaware of the possibility of their own bias. Herbert Butterfield's critique of Herodotus is a lovely example of the way in

which the critic is ironically exposed by his material:

> He wrote history partly in order that great deeds (whether of Greeks or non-Greeks) should be placed on record, and partly because he wished to lay out the causes of the Greco-Persian war. He was interested in the way in which things came to happen and would look for rational explanations, showing the influence of climate and geographical factors and presenting excellent portrayals of character, though he was liable to impute important events to trivial incidental causes, the influence of woman (sic) and purely personal factors. At the same time he had a disturbing sense of supernatural influences, showed the inadequacy of human calculations, the retribution that Heaven would inflict on great misdeeds, and introduced dreams, oracles, visions, and divine warnings of approaching evil.

With Herodotus we might cite the great Roman historians, Alfred and Shakespeare on English history, Vico, Burke, de Tocqueville, Burkhardt, and Huizinga as all in one way or another recognizing the fundamental importance of values as the driving force of history. Shakespeare especially is an exemplary historian of the persuasion I wish to urge; more than anyone else he sees how together we make up the drama of history according to what we deem to be the best, and how from that loom flows the rich pattern of human events.

It might well be objected that I am advocating an outrageous abandonment of objectivity, and giving license to the worst forms of ethnocentrism and bias. Indeed, I must plead guilty, but with mitigating circumstances. It was the age of "objective" history that provided the fuel for scientific racism, holocausts, colonialism, and the Gulag. The ideologue who believes he has objective truth on his side is more dangerous than the ordinary patriot or hero, because he calls his values "facts" and will disregard all ordinary human values in their service. We are going to be ethnocentric anyway; let us at least play our ethnocentrisms against each other on a level playing-field and not attempt to get the objective high ground of each other. Given such a game, in the long run adaptive success attends those versions of our partisanship which have the widest, pan-human, appeal. Let us not seek to avoid bias, but to widen our bias in favor of the whole human race, and beyond.

This approach especially questions the apparent straightforwardness of the notion of political power. Events occur, and their meaning is rich and complex. The events are made up of the actions of men and women; and if they performed those actions then tautologically they had the power to do so.

Do we gain anything by inserting the idea of power? Suppose they didn't perform the actions; could they have? Could we prove it? Power depends on values, and values on the individual and collective imagination.

Even the very methodology of historical research may have to be profoundly modified if the new view of history is to prevail. A perceptive critic of historiography, Gene Wise (*American Historical Explanations*) has already pointed out some of the fallacies in the accepted model of historical research, in which "primary sources" (contemporary documents and suchlike) are valued more highly than secondary ones (e.g. later interpretations by historians) and they in turn are preferred over tertiary discussions and revisions of historical interpretations. He rightly declares that the only true primary source is the actual experience of the participants in historic events. All other sources are secondary and partial filters; but the nature of the filter itself is part of history, and perhaps a more crucial part than we think. R. G. Collingwood said: all history is the history of ideas. Or we might put it this way: history (small h) is History (capital H).

Perhaps we could go even further and remark that much contemporary documentation may paradoxically be worse evidence than later judgments by hindsight. Consider an analogy: the information-processing system of the human eye and visual cortex. If "primary" evidence is better than secondary, then the best visual data about what is happening in the "outside world" is the raw firing of the retinal neurons. The work of the optic nerve and visual cortex would amount to nothing more than a heap of opinion and sophistry. The military technologists who wanted to design an eye by which homing missiles might recognize their prey took this position at first, but they were soon proved wrong. Their attempt to hook up a TV camera to a simple computer programmed with pictures of enemy tanks simply did not work. The raw data did not add up to tanks but to a riot of shadows, colors, changes in reflectivity and albedo, geometric distortions by perspective, and confusing shifts which could not distinguish between subjective motion, motion of the object, changes in the object, and changes in light and shadow. To make a catalog of all the appearances a tank might take on would require a memory as big as the universe, which, moreover, could easily mistake something else for a tank. Later work by Artificial Intelligence researchers like Marvin Minsky and vision scientists like Edwin Land and David Marr revealed the astonishing hierarchy of ganged or independent servomechanisms that makes up vision, and its radical dependence on prior expectations, needs, or questions to make any sense of the world at all. In other words the secondary and tertiary sources are much more reliable than the primary ones, to use the old classification.

Further, of course, the physical world is, as we know now from quantum theory, constituted as such by the cooperation of sentient beings. Thus, tanks don't look like tanks and can't act as tanks without being interpreted as tanks; their tank existence derives from the secondary and tertiary data. And of

course this analogy is more than an analogy, but a further deconstruction even of Wise's notion of "experience." If the old hierarchy of primary and secondary is so problematic for visual experience itself, think what it is for the process of historical evidence-gathering. What history really is is our interpretation of it. We are all, in the deepest sense of experience, contemporary experiences of those historical events; quite as much as the astronomers are contemporary experiencers of the supernova that exploded one hundred sixty million years ago and whose light has just now hit their telescopes. We can with relief relinquish the positivism of the old mainstream historical research; after all, the physicists abandoned it fifty years ago.

We can abandon, too, that kind of history which assumes always that there is a true, hidden version of events, of which the apparent surface is a hypocritical coverup. Of course hidden motives and interests do govern what goes on; but everybody has such motives, and everybody is a player in the game, a partner in the feedback. If the population is deceived, it may be because it wants to be deceived and, if the deceiver is unveiled, will get itself a more competent magician and a more satisfying illusion. And such collective creations, in this contingent world of ours, verily constitute reality. The surface of history *is* the reality, and the new historiography will treat it as an expressive, meaningful, but inexhaustible artistic object, and not seek only to reveal an inner truth that derives from initial conditions or a conspiratorial *deus ex machina*.

This means that the capacity to recognize beauty, the esthetic sense, is the primary cognitive skill of the historian or sociologist. It is by beauty that we intuit the order of the reflexive process of human history. On the small, tribal scale the need for this essential function may well have been one of the principal selective pressures that led us toward our extraordinary inherited talents at storytelling and the interpretation of narrative. History should be refounded on story, not the other way round. Indeed, much of the most exciting new work in sociology -- for instance the work of Thomas Scheff -- is beginning to take this direction, and to break free from its positivistic traditions; cultural anthropology, with its participant-observer methods and its tradition of listening to native informants, did not have very far to go.

If the new definition of historical understanding is that we understand what we are able to model, and if our new definition of evidence is experience, how do we model and experience history?

I would suggest a number of ways, some of which are already being used unsystematically and without theoretical justification, but very effectively nonetheless. Almost all of them involve a greater or lesser degree of collapse between the activities of teaching, learning, and research -- which would be no bad thing for our academies.

First, historical reenactments. Popular culture, as often, is ahead of the

academics. The reenactment of Civil War battles and the battles of Texan independence has become a vital and creative popular movement. Historians should pay close attention; the experience of the "soldiers" is apparently extraordinarily intense and often not what one would expect. Of course, reenactment need not be confined to military events.

Second, ethnodrama, which is a new technique designed by anthropologists and performance experts to enact central ritual or social activities from other cultures and periods -- marriages, funerals, and other social dramas. The Smithsonian, to its credit, has recognized the historical value of this form of knowing by doing.

Third, the use of events taking place now, of which our experience is peculiarly sharp, to partially model past events. Those modern events may be the more useful as models, because of their divergence from their analogue. For instance the current state of conflict in the Middle East may valuably model the Thirty Years' War in Germany, and the other postrenaissance religious conflicts in Italy and France.

Fourth, wargames and their extension into the diplomatic, social, and economic spheres. Wargames have in the developed world now largely replaced actual battles as the most efficient way of resolving military struggle; we are engaged in such a war with the Soviet Union at this moment, and have been for some years. The actual weapons are little more than gold reserves, so to speak, kept in the bank to support the working currency, which is the games. With the advent of better computers we should be able to game-model a variety of historical situations and cultural processes, altering the parameters, variables, and degrees of feedback until we get a course of events which matches the historical data. The point is, the data need not be especially rich, or even reliable, to provide, as an ensemble, extremely rigorous and exclusive criteria to be satisfied by the model. Leontieff's mathematical model of the economy of the United States is a nice example of what can already be done along these lines.

Finally, I would suggest the careful attention to fictional and dramatic accounts of history, their performance, and even their fresh creation. This is a time-honored and enormously fruitful practice; but it may be even more fruitful if we treat it as serious historiography. Here we may test the validity of historical ideas by seeing whether the events of history are psychologically and narratively consistent with the fictional model.

We are perhaps ready now to apply Marx's dictum -- that the point was not to understand history, but to change it -- in a way quite different from what he intended. That art which changes history may be its most intimate and precise study.

Nonlinear Science and the Unfolding of a New Intellectual Vision

Alan D. Beyerchen

There is every reason to believe that the westernized world is in the early stages of an intellectual transformation of major proportions, perhaps as significant as the emergence of the modern worldview in the fifteenth through seventeenth centuries. In support of this contention, I would like to make two observations. One is that the values and procedures of science are so thoroughly intertwined with the modern worldview and suffused throughout western culture that major changes in those values will have repercussions for all of us who participate in that culture. The other is that science is indeed undergoing changes of far-reaching consequence. The pervasiveness of science and its authority is sufficiently self-evident that it needs only brief defense here. The second, however, requires more sustained attention, particularly with regard to developments surrounding what has come to be known as "nonlinear science."

The authority of science is largely rooted in the worldview of deterministic, time-independent and universal laws enunciated in western European society during the seventeenth century, especially with the synthesis achieved in Galilean-Newtonian physics. The work of political, social and economic theorists of the seventeenth and eighteenth centuries such as Hobbes, Locke, Montesquieu, Smith, and Kant, was grounded in the science of that time. During the nineteenth century, the Darwinian idea of natural selection and the general impact of time-dependent (i.e., evolutionary, such as thermodynamic) conceptual schemes were subsumed, albeit uneasily, within the Newtonian framework. In the first half of the twentieth century, the Newtonian worldview was challenged for phenomena at very high velocities and large scales (relativity theory) or very small scales (quantum mechanics). These emendations seemed far removed from daily life, however, and in areas such as medicine, economic policy-making, technological innovation, strategic military planning, or advertising, the

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"common sense"scientific approach has remained fundamentally Newtonian.[1]

This twentieth-century reliance on a seventeenth-century mindset has not escaped criticism, nor have the implications of fitting social phenomena into the molds shaped by the methods and authority of the physical sciences. One recent critic, the political scientist Benjamin Barber, has challenged the Newtonian "preconceptual frame" and the "Cartesian epistemology" embedded in the methodological individualism that underlies western notions of human interaction. He notes that classical individualism posits a material world broken into its component parts and founded on a subject-object dichotomy in which the observer occupies a privileged position outside the system under observation. Human beings are viewed as atomistic, independent, autonomous bodies, indivisible in motives, interchangeable with one another as observers and objects, perpetually in conflict with each other, and responsive only to physical sensations.[2]

Barber could also have listed examples of the way language and thought are laced with specific but largely unexamined metaphors drawn from science: balance of forces, social inertia, catalysts of change, the political spectrum, the swing of a political pendulum, and other images commonly used in historical explanation demonstrate ways in which science frames our thoughts even in areas traditionally regarded as part of another way of looking at the world. The reciprocal legitimation of science by progress and of progress by science is a hallmark of western culture, often accepted implicitly even by outspoken critics of the West. Major changes in the procedures or objects of interest in science affect not just scientists, but everyone who lives in a culture that assumes the "common sense" of a scientific worldview.

The changes that are occuring in science arise from many interwoven factors, ranging from the scale of the enterprise to the shape of its authority, but the one that most interests me here is the computer. Most non-scientists think of the computer in terms of its typewriting function as a word processor or its calculating mode as a glorified adding machine: it makes life easier by performing some basic tasks more efficiently. Yet these uses are trivial in comparison with the computer's real impact which most persons experience primarily through the visualization and modelling techniques used in such entertainments as arcades and video games. In science, however, the related but more sophisticated forms of computer graphics are altering the very structures of our perceptions as well as our conceptions of the world around us.

As is often the case with fundamental human issues, the ancient Greeks had important insights. Just before the parable of the cave in the *Republic*, Plato sketched a hierarchy of knowledge in which the first level was *eikasia*, "imagizing" (from *eikon* = image). From there the levels rose through believing (*pistis*) and thinking (*dianoia*, the level of mathematics) to knowing

(*noesis*). Plato regarded each level as superior to the one below, but also as predicated upon it. The most basic of all -- the one on which all the others rested -- was that of images. We implicitly retain this notion whenever we use phrases such as "oh, I see" or "that's my view, too" to indicate understanding or agreement. The underlying social importance of vision is implied in the fact that the cave paintings at Lascaux predate writing by more that 15,000 years, and its evolutionary significance is suggested by the fact that, according to some estimates, up to half of the human brain is tied to visual centers and to the processing of visual information. "Imagizing" is too often undervalued because we categorize it as less sophisticated than higher levels of abstraction, but its very primitiveness makes it a filter through which "higher" understanding must pass.

Changes in our ability to "see" have in the past had a substantial impact not only on science, but on our conceptions of reality and our interaction with our environment and with each other. Consider for a moment the shapes of objects as conceived in geometry and how greatly geometry influenced the minds of the Greeks and of all those affected by their ideas. Recall the impact of the telescope and microscope in the seventeenth century and how they modified our later assumptions about the workings of the universe and about the place of human beings in the natural world. Simple reflections like these help reveal the meaning of such catchphrases as "seeing is believing."

What we see, and, more specifically, how we *value* what we see, is managed by the aesthetic judgments we make. Evaluations are usually guided by rules learned through acculturation and professionalization, but aesthetic considerations constitute one of the most important ways in which we justify the less conscious processes that govern our formulation and understanding of the rules by which we usually operate. In the sciences as elsewhere in life, such "meta-rules" are conditioned by training and experience. They are particularly crucial at the forefront of scientific research, where the new rules are by definition uncertain and where intuition often becomes one of the best guides for the researcher. What looks and feels "right" probably is right in the sense that it would seem reasonable to others in the field as well.[3] A change in understanding a given phenomenon or rule is minor in comparison with change in intuition, and the realm of intuition is the area in which the computer is changing values most radically.

Modern science has been guided since its inception by an aesthetic of simplicity, and an alternative wrought by the computer is essential to the transformation that is in process. There is no higher compliment in science than to praise an idea or an expression as elegant. There is no better way to decide a scientific argument than by resorting to parsimony. Idealizations are permitted to question our sense of reality on behalf of a higher, truer sense of beauty that lies in the realm of the simple. In comparison to relations in this realm, our experiences are regarded as merely cluttered approximations --

think of the archetypical examples of the frictionless pendulum or the point-mass billiard ball on a frictionless plane. Simplicity and parsimony have legitimated the thought processes by which we close off most of the universe in order to "isolate" a given system. They legitimate our aspiration to hold the maximum number of variables constant while we manipulate the remaining few (preferably one) of immediate interest. The formidable analytical tools of mathematics can thus be brought to bear, as they have been with great success in fields like physics and astronomy, allowing us to predict the behavior of such an isolated system. We are very knowledgeable about systems that can be treated as if they were isolated and simple, and we have very sophisticated tools for dealing with them.[4] Even in physics, truly complex phenomena (such as turbulence in fluid dynamics) have presented largely intractable problems.[5]

Through numerical techniques, the computer offers us the ability to expand our vision to define the complex context in which our simple, idealized, isolated systems function. In an article in *Science*, the Director of the National Supercomputer Applications Center at the University of Illinois, Larry Smarr, has indicated what such expansion means. Rather than being limited to the mindset in which the classical laws of nature have been described, namely the linear analysis of partial differential equations for a continuum field, Smarr argues that supercomputers make it possible to turn to the nonlinear equations that describe so many of the phenomena that occur in nature. The use of finite differences instead of the infinitesimal differentials of calculus replaces the space-time continuum with a discrete space-time lattice of events, and, with enough time, a computer can solve the algebraic system representing the field's values at each point in the lattice. As the spacing of the lattice is reduced, the discrete solution may approach that of the continuum. In other words, a *very* large number of values for the unknowns can be placed into an equation or set of equations, and a solution might be found that is approximate and realistic rather than definitive but ideal. As Smarr notes, "The result is a revolution in our understanding of the complexity and variety inherent in the laws of nature."[6] The result has also been a disconcerting increase in the variety of approaches to science:

> Too often misunderstandings arise between scientists trained in classical analytical methods and those for whom numerical methods are the primary research tool. One often hears: "Numerical solutions are inelegant," or "Analytic solutions are simplistic." Such comments reveal a clash between two coexisting aesthetics derived from the nature of the computational tools that are used.[7]

The rise of an aesthetic of complexity in science represents a significant challenge to the primacy of simplicity.

A change in aesthetics means a change in the meta-rules according to which other rules are generated and judged. This includes the rules employed by astrophysicists such as Smarr, who contends that the quest for form is shifting from the laws of physics (presented in "skeletel view" by analytical solutions) to patterns in the solutions of the equations for the laws. Attention is turning from static equilibria and symmetry to dynamic equilibria and asymmetrical, time-dependent (evolutionary) phenomena. As Smarr explains:

> The beauty of the ever changing three-dimensional structure of clouds is surely as great as the beauty of a perfect crystal. To explore such phenomena as the clouds requires the ability, which numerical tools give us, to probe complexity.[8]

Searching for a bond between the two clashing aesthetics, he stresses the ability of each to encode what is "visually beautiful." The use of color images and other computational devices can offer the eye the kind of satisfying beauty that has also been found in graphing analytic functions.

Mathematician Norman Zabusky at the University of Pittsbugh, who is an advocate of the numerical approach and computer graphics, agrees with Smarr:

> We are in the midst of a computational revolution that will change science and society as dramatically as the agricultural and industrial revolutions did. . . . Supercomputers with ultrafast, interactive visualization peripherals have come of age and provide a mode of working that is coequal with laboratory experiments and observations and with theory and analysis.[9]

With today's computers it is already possible to go beyond equations adjusted to find stationary configurations and their responses to weak perturbations, for we can explore nonlinear and complexly intercoupled phenomena. Zabusky argues that this line of inquiry will produce remarkable new insights as the range of supercomputer capability grows. He even compares the historic importance of the associated ultrafast graphics systems with that of the early particle accelerators. The impact of this new capacity will "affect not only scientific innovation and technological productivity, but also political, economic and military decision-making."[10] If Smarr and Zabusky are accurately stating the case, then we have already embarked upon a course that will fundamentally change our ability to "see" complexity.

* * *

Both Smarr and Zabusky frequently mention the innovative expansion of our ability to deal with "nonlinear" phenomena and the equations used to describe them. Neither the phenomena nor the equations are at all new or difficult to encounter. In fact, nonlinearity is so commonplace that mathematicians and scientists must often find a way to eliminate nonlinearities by "linearization" of the equations describing the system under examination.

"Nonlinear presupposes a sense of what is "linear." Linearity involves two propositions: 1) changes in system output are proportional to changes in input (proportionality), and 2) system outputs corresponding to the sum of two inputs are equal to the sum of the outputs arising from the individual inputs. The first means that the effect of an input is related to the output by a constant, so that $F(ax) = aF(x)$, yielding proportional returns to scale. This means that no synergism is allowed in a linear system. The second indicates that we can deal with the effects of a system either as a whole, or we can break it into its component parts and then add the effects of the parts together to represent the effect of the whole, so that $F(x+y) = F(x) + F(y)$.[11] Such systems are termed "linear" because their properties are those with a relationship between the variables that can be plotted as a straight line. As Smarr indicated above, linearity is appropriate to a search for laws of nature and entails notions of symmetry, time-independence and static equilibria. It also encourages us to isolate variables, focus on the consistency of regularities, and construct models that employ causal trains to predict the behavior of a given system. Because systems perceived to be linear are relatively simple, we have come to understand them rather well over the centuries, and linearization has been a very useful technique. But, as with any powerful mode of thought, it has generated many possibilities while blinding us to others. To the person who has only a hammer, as the saying goes, every problem looks like a nail.

The computer has made it possible to deal with problems by numerical techniques far too laborious to perform by hand, thereby creating a way to cope with the ubiquitous nonlinear systems that do not obey the rules of linearity. (In some cases these are open systems that are highly "sensitive to initial conditions" precisely because their variables cannot be isolated from their surroundings or from each other.) This approach leads from models offering analytical predictions to an approach in which the realm of solutions must be explored through what is called "experimental mathematics" or "computer experiments." Often the goal is to manipulate the parameters as well as the unknowns in the equations. The parameters are usually constants or selected variables treated as constants which are varied over a range of values, generating a system of equations representing entire families of lines or surfaces.[12] The resulting focus on a coherence of dynamic forms rather

than a consistency of stable content means that the boundary conditions and changes over time take on a new interest. Construction of context and attention to the frequently untidy limits of stability become as important as the relatively simple center of stability.

This sounds quite abstract, but the nonlinear problems are as pragmatic as combustion, turbulence, heart fibrillations, deep ocean currents, population ecology, and weather patterns. The key to understanding such phenomena is the development of a new *intuition* with which to confront them and the massive amount of data about them generated by large scale computer simulations. This is the point at which *interactive* computer graphics comes in. As a National Research Council report on "Physics through the 1990's" explains:

> One is no longer surprised at seeing a serious mathematician in front of a graphics terminal. Five years ago, a mathematician could risk losing contract support if funding was requested to purchase such a terminal. Simply, it is now accepted that intelligent exploratory computation makes its users more intelligent than they could have guessed they would be. A great mathematician will regularly say that once one knows what is true, the proof is easy. . . Once a setting is uncovered that possesses hints of orderliness in a context of complexity, one can manipulate the object until seeds of intuition appear. Our inheritance of experience with simple systems is strikingly empty of images, intuitions, and methods for dealing with nonlinear problems of complexity. We know almost nothing of the workings and accustomed regularities of such systems. And to proceed we must come to know them intimately.[13]

To develop an intuition for this kind of knowledge, all of us, not just research mathematicians and scientists, will have to sharpen a new (but also, as I have noted above, very ancient) skill to augment those of literacy and numeracy.[14] In order to remain with a Latin root, we can draw upon the word "pictorial" and coin the term "pictoriacy" to designate the capacity to deal effectively with complex images and the data they embody.

The deep resonance of a heightened "pictoriate" sensibility has already been demonstrated in numerous images used by scientists and mathematicians to explore the phenomena of interest in nonlinear science. The pictures generated by their computers carry enormous amounts of information, but are additionally so compelling that journals such as *Science*, *Scientific American*, and *The American Scientist* have been joined by newstand publications such as *The Economist*, *Newsweek*, and *The World & I* in presenting them to fascinated readers. Companies have sprung up near

research universities to produce videotapes, slides, posters, and even postcards of these computer-generated images for the general public. A television advertisement for IBM proudly presents one of its mathematicians in front of a computer display of his innovative mathematical objects. The pages of *Mosaic*, the National Science Foundation magazine published to acquaint a policy-making audience with the achievements of Foundation-supported scientists, have repeatedly been devoted to stories that could be illustrated by the striking pictures culled from nonlinear science. A book that chronicles some of the key personalities and research in the field reached the *New York Times* bestseller list.[15]

Some of the most stunning images have been termed "fractals" by Benoit Mandelbrot, the mathematician IBM features in its advertising. They are members of a century-old class of mathematical objects that most late nineteenth-century mathematicians thought of as "pathological" or "mathematical monsters." Each fractal is characterized by a measured dimension that contrasts with its ordinarily defined dimension in Euclidian geometry, where a point has zero dimension, a line one, a plane two, and a volume three. What does this mean in practice?

One of the examples Mandelbrot uses to illustrate the nature of fractal geometry is the coastline of England, which is notoriously crinkled due to all its bays and inlets. On a map of a given scale, an overall length can be determined by applying a ruler of a given length along the image of the coastline. However, if a shorter ruler is used, more precision in tracing the bays and inlets can be obtained, and the numerical value for the overall length increases. With a yet shorter ruler, the length increases further still. Mandelbrot concluded that we can achieve a length that is approximate and realistic, but that no definitive value for the length is possible. There is, however, a constant logarithmic relationship between the length of the measuring rod used and the number of times it is applied. Empirically, that relationship for the coastline of England is approximately 1.26, a fractal dimension that intuitively implies that the coastline is so crinkled that its twists and turns describe a shape that is more than a Euclidean line, but less than a Euclidian area. Smoother coastlines have fractal dimensions closer to the Euclidian ideal of one.[16] In general, fractals provide a measure of the jaggedness of a line or the roughness of a surface. They have proven to be of importance in understanding practical phenomena ranging from viscous fingering in oil drilling (a tendril-like fanning out processs experienced when a less viscous fluid such as water tries to push a more viscous fluid such as oil) to bronchial branching relationships in the human lungs to the surface properties of complex molecules such as proteins.[17]

Mandelbrot has also used a surprisingly simple expression on the complex plane to produce interesting examples of fractal complexity. The process is iteratively to map z to $z^2 + c$, where z is a variable and c a constant. In the first step $z^2 + c$ becomes $(z^2 + c)^2 + c$, in the second you square the result

and add c again, which becomes $((z^2 + c)^2 + c)^2 + c$, etc. [18]

Since the squaring process is a familiar, garden variety nonlinearity, conventional intuition would anticipate nothing very startling. Most numbers might be expected to grow quickly very large and race outward toward infinity, while numbers close to the origin on the plane might be expected to head inward toward the origin at 0,0; the boundary between the two groups should thus be fairly sharp. This is precisely what happens when c = 0, so that we are squaring the initial point z each time, or, $z_0 \mapsto z_0^2 \mapsto z_0^4 \mapsto z_0^8$. Any initial point less than an absolute distance of 1 from the origin becomes smaller with each iteration (in which case the origin is the "attractor" toward which they move). Each initial point greater than a distance of 1 becomes larger with each iteration (in which case, infinity is the attractor). And each point at an absolute distance of 1 from the origin stays at that distance indefinitely, forming a clean boundary.

When z rather than c is equal to 0, however, the inner attractor is affected by c and is no longer at the origin; instead of a perfect circle with radius 1, the crumpled, fractal boundary of a "Julia set" emerges. [Figure 1] These sets display the intriguing property that under increased precision of resolution they retain "self-similarity." A Euclidean sphere from a great distance looks like a point; seen from closer it appears to be a disk; closer yet its spherical shape is apparent; from very close, however, it may seem to be a plane. A fractal retains its appearance over many scales, and Julia sets have "interesting" (non-repetitive) self-similarity that is reminiscent of a jagged coastline.

Furthermore, when you track an increasing succession of possible c, you can cross a boundary where the Julia set seems to dissolve, its shape no longer intact. [Figure 2] When all the points c that produce the connected Julia sets are gathered together, they form a set that has been named after Mandelbrot. The boundary of this set turns out to be exquisitely complex, with a menagerie of different Julia sets within its domain. [Figure 3] With color computer graphics, it is possible to work through a dizzying exploration of richly surprising imagescapes dotted with smaller versions of the initial shape of the entire Mandelbrot set.

It is astonishing to realize that the images arise merely from the dynamics of the operation which sends z to $z^2 + c$ when its context (the parameter c) is systematically surveyed. The entangled, filagreed boundary between two competing attractors is a sign of the enormous complexity that may lurk in the apparent simplicity of a nonlinear expression. [Figure 4] One mathematician has reputedly termed the Mandelbrot set "the most complicated object in mathematics."[19] Only the use of numerical techniques and interactive computer graphics, championed by researchers such as Smarr and Zabusky, could have made its intricacies manifest outside a small circle of specialists.

It is no coincidence that Smarr cited the ever-changing beauty of clouds as equivalent to the beauty of a perfect crystal, since one of the immediate applications of fractals has been the computer generation of shapes that look much more like real clouds than any of the forms produced by other graphics techniques. Not only clouds, but ridge lines, silhouettes of forests, individual plants, mountains tops, and other natural objects are more realistic-looking to the human eye when presented in fractal dimensions. The usual treatment in Euclidean dimensions generates images that seem too uniform and man-made, as indeed they are. The interaction of elements of complex order strikes many people as deeply satisfying, rather like the ever-changing patterns of flames in a fireplace or the swirling patterns of water in a stream.

Other images from nonlinear science are also fascinating. Among the most powerful of them are perhaps those of deterministic chaos, in which systems described by deterministic laws can exhibit long-term unpredictable behavior. As David Campbell, Director of the Center for Nonlinear Science at Los Alamos National Laboratory, explains:

> That a system governed by deterministic laws can exhibit effectively random behavior runs counter to our normal intuition. Perhaps it is because intuition is inherently 'linear'; indeed, deterministic chaos *cannot* occur in linear systems. More likely, it is because of our deeply ingrained view of a clockwork universe, a view that in the West was forcefully stated by the great French mathematician and natural philosopher Laplace. If one could know the positions and velocities of all the particles in the universe and the nature of all the forces among them, then one could chart the course of the universe for all time. In short, from exact knowledge of the initial state (and the forces) comes an exact knowledge of the final state. . . . However, in the real world exact knowledge of the initial state is not achievable. No matter how accurately the velocity of a particular particle is measured, one can demand that it be measured more accurately. Although we may, in general, recognize our inability to have such exact knowledge, we typically assume that if the initial conditions of two separate experiments are *almost* the same, the final conditions will be *almost* the same. For most smoothly behaved, 'normal' systems this assumption is correct. But for certain nonlinear systems it is false, and deterministic chaos is the result.[20]

These difficulties were recognized long ago; the mathematician Henri Poincaré, for example, called attention to them at the turn of the century. They were not addressed until recently, however, for as Campbell observes, chaos defies direct analytic treatment. The seeds planted by Poincaré could

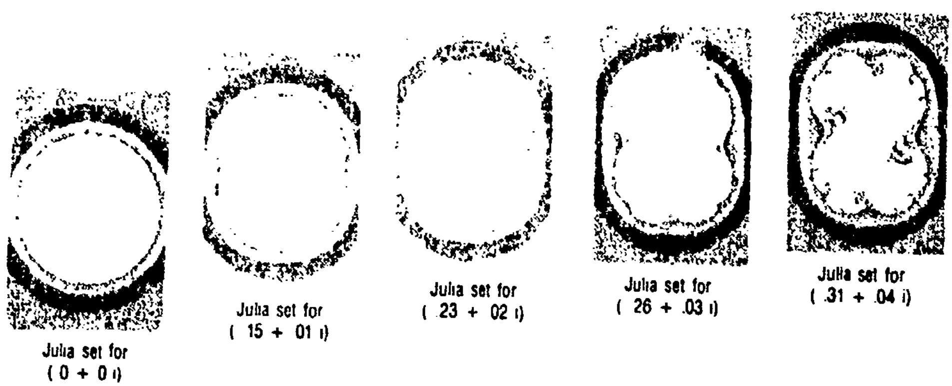

Figure 1
Examples of the results of iterating $Z^2 + C$ on the complex plane with Z initially O. On the left is the circular Julia set at the origin on the plane, with increasing deformation of the circle as the selection of C moves along both the positive and imaginary axes to the set at .31 real + .04 i. The jagged boundary of the Julia sets is fractal.

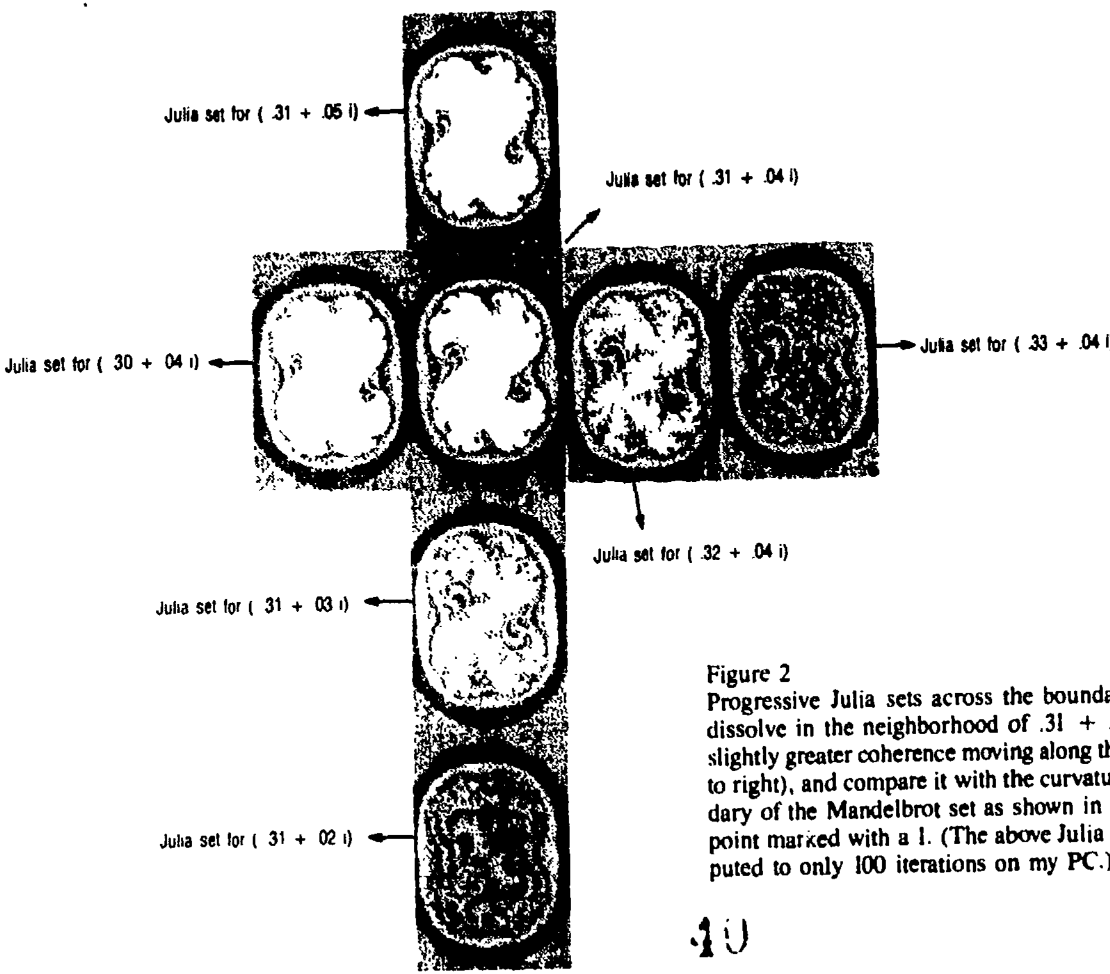

Figure 2
Progressive Julia sets across the boundary where they dissolve in the neighborhood of .31 + .04 i. Note the slightly greater coherence moving along the real axis (left to right), and compare it with the curvature of the boundary of the Mandelbrot set as shown in Fig. 3 near the point marked with a 1. (The above Julia sets were computed to only 100 iterations on my PC.)

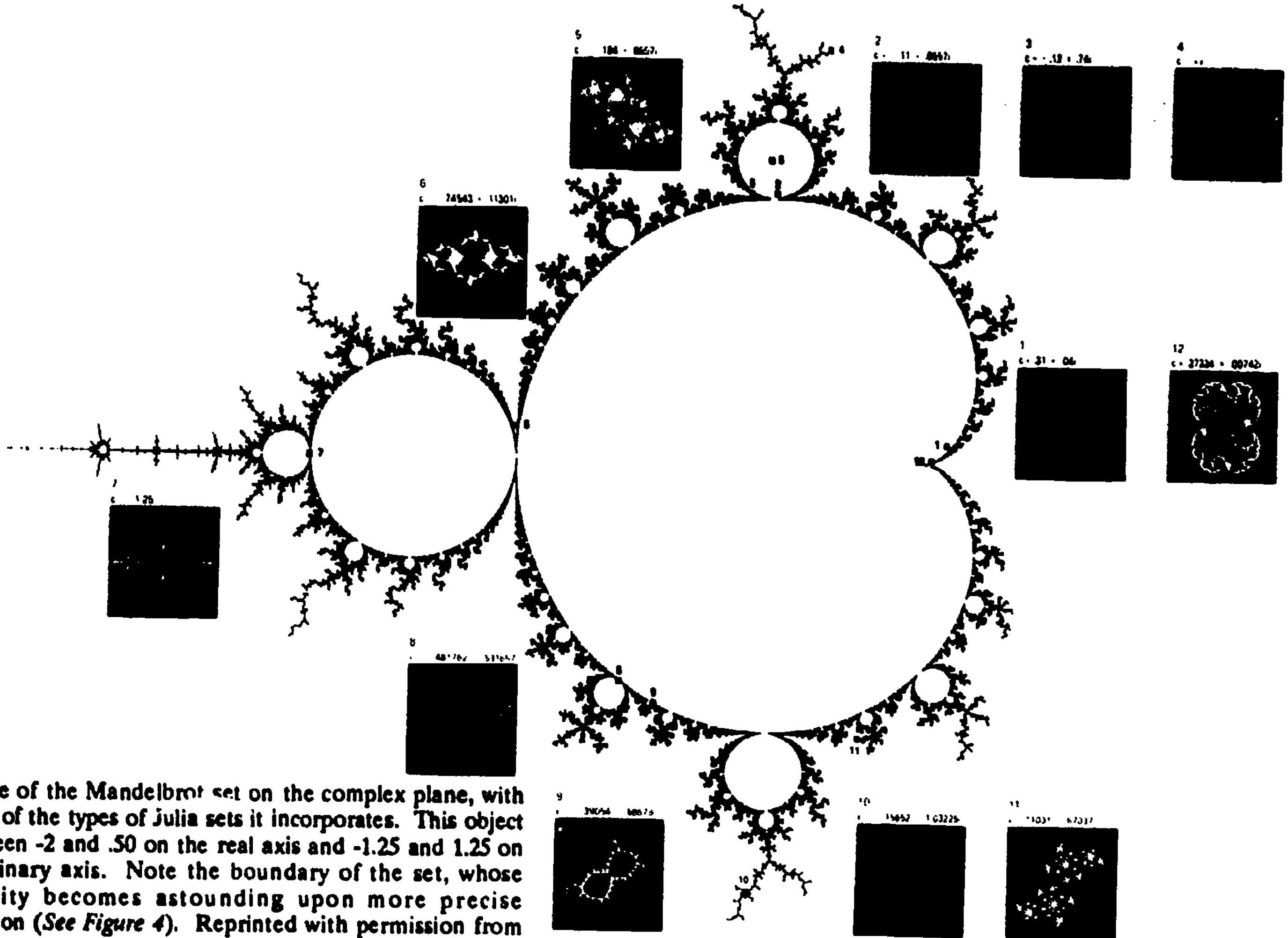

Figure 3
The shape of the Mandelbrot set on the complex plane, with examples of the types of Julia sets it incorporates. This object lies between -2 and .50 on the real axis and -1.25 and 1.25 on the imaginary axis. Note the boundary of the set, whose complexity becomes astounding upon more precise examination (*See Figure 4*). Reprinted with permission from the award winning book *The Beauty of Fractals* by H.-O. Peitgen and P.H. Richter, 1986, Springer-Verlag Heidelberg New York.

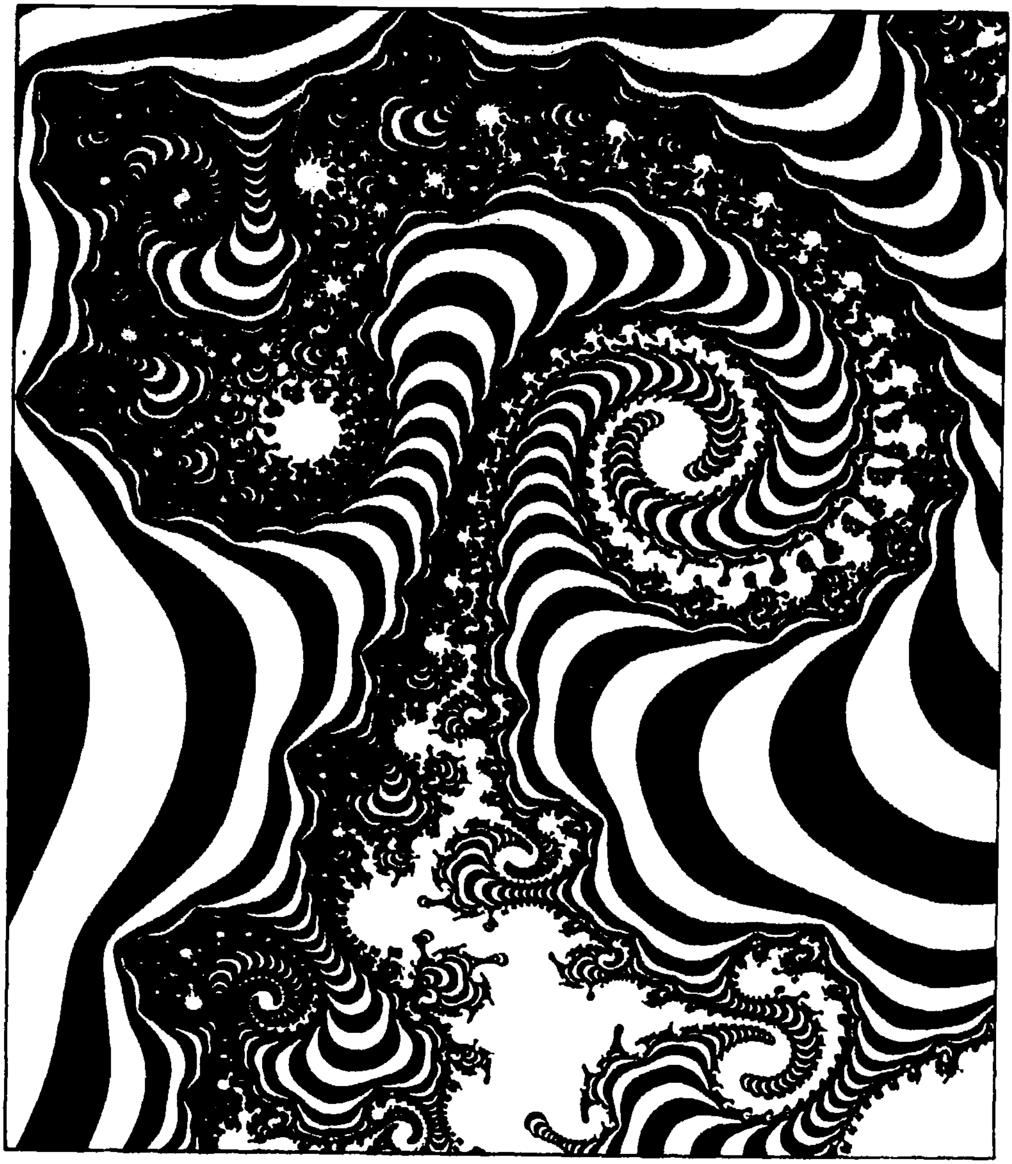

Figure 4
A glimpse of a portion of the complexity embodied at the boundary of the Mandelbrot set. This image can serve as a metaphor for the complexity that bedevils the humanities at every turn. Reprinted with permission from the award winning book *The Beauty of Fractals* by H.-O. Peitgen and P.H. Richter, 1986, Springer-Verlag Heidelberg New York.

only germinate when the advances in interactive computation made experimental mathematics a reality."[21]

The key visual concept is the representation of a "phase space," in which the state of a system is given by a point and its behavior over time by a trajectory in that space. The resulting geometrical forms provide a way to characterize and classify the behavior of the system. For example, a closed loop represents a periodic behavior because the trajectory begins to traverse points already covered as the system returns to its initial state and repeats its earlier behavior. A pendulum damped by gravity swings back and forth and finally comes to rest; its behavior when plotting position against momentum would be represented by a trajectory that spirals down to a single point because, upon reaching a stable equilibrium, no further change occurs over time. Dissipative systems such as the damped pendulum are characterized by contracting area or volume in phase space as they are "attracted" to their end state.

An attractor with a fractal dimension, dubbed a "strange attractor," indicates that, although the system's behavior is coherent in an overall sense (otherwise there would be no attractor at all), its behavior never repeats itself exactly. In deterministic chaos, two typical starting points separated by an arbitrarily small distance, that is, two states of the system arbitrarily close together, can diverge from each other exponentially over time on an attractor or even be drawn to different attractors. Thus, a very small uncertainty in specifying the inital state of the system quickly leads to a loss of ability to predict its future, even if the equations describing its behavior are deterministic and known.[22] This is what is meant by "sensitive dependence upon initial conditions."

Because they have drawn attention to some fundamental issues concerning complexity and unpredictability, computer graphic displays have been both spectacular and unsettling. It is not surprising to learn that one of the first instances of a strange attractor in a physically interesting model was discovered in meteorology, where the global weather system proved to be so sensitive to initial conditions that, literally, a butterfly flapping its wings in one part of the world could later produce a large-scale weather effect somewhere else. The implication of deterministic chaos is that, for many nonlinear systems, predictability is problematic. Furthermore, it seems that variation of the parameters (i.e., a change in context) can display intricately intermixed regimes of stable and unstable behavior, while many different routes to chaos can be followed. Indeed, it has become clear that fundamental problems of the relationships between order and randomness are involved. A recent article exploring basic concepts in the field closes with a long list of questions and the final observation that "these are only a few questions. There are many more, and probably the most important questions are those that have not yet been asked."[23]

Scientists and mathematicians have stalked the ramifications of chaos, strange attractors, and fractals into the thickets of biology, cognitive science, and information theory. One early proponent of chaos studies stated flatly: "Evolution is chaos with feedback."[24] A second National Academy of Science volume on "Physics through the 1990's" enthusiastically concludes:

> There are a number of important biological applications of nonlinear dynamics, especially to neural networks. The idea that memories can be represented by attractors in a dynamical system is an appealing concept that may be capable of explaining some of the important properties of memory, such as the ability to recall a great deal of information starting with a small part of it.[25]

A group of early contributors to the field argued recently that "chaotic attractors act as a kind of pump bringing microscopic fluctuations up to a macroscopic expression," suggesting that they are a form of information generator. These authors also argue that chaos challenges the widely held view that systems can be understood by reducing them to their components and studying each part separately. Instead, "a system can have complicated behavior that emerges as a consequence of simple, nonlinear interaction of only a few components." This insight opens the doors not only to a better understanding of the role of novelty in evolutionary processes, but perhaps to explanations of how random changes are structured in human thoughts, in creativity, and in the exercise of free will.[26]

Fractals and deterministic chaos are only two of the new vistas that are unfolding in the intellectual landscape of nonlinear science. When the renowned mathematician Stanislaw Ulam remarked that using the term "nonlinear" was "like defining the bulk of zoology by calling it the study of 'non-elephant animals,'" he was making the point that the vast majority of natural phenomena and mathematical equations are actually not linear.[27] Coherent structures like solitons (nonlinear solitary waves that preserve their structure even when they collide with other objects), complex configurations such as self-organizing patterns in systems far from equilibrium, nonlinear equations of prey-predator or host-parasite relationhips in population ecology, and "cellular automata" that generate complex patterns from relatively simple algorithms in computer programs all raise important new questions. A mathematician recently declared that the person who could find a way to link all these areas qualitatively and quantitatively would be the Newton of the twenty-first century.[28] There seems little reason to doubt that the new synthesis will be as pervasive as has been Newtons for the past 300 years.

* * *

Given the potential magnitude of the transformation of our vision currently underway and the fact that even those researchers involved are not certain what questions need to be asked, trying to anticipate the impact of these changes outside laboratories and computer facilities is not easy. The temptation to offer a discipline-by-discipline survey of their ramifications across the sciences (including social sciences), humanities, and fine arts must be resisted, for such an undertaking would correspond to the very subsystem-isolating mind-set that is in the process of being questioned. Such an approach would only reflect the compartmentalization of knowledge that is the culture-bound legacy of a form of linearization derived from the aesthetic of simplicity.

Instead, I will try to weave my way through two mutually entangled sets of implications. The first is the growing importance of the skill Plato called "imagizing" and I have termed "pictoriacy." The second is the boundary between the sciences and the humanities. A common parameter is the legitimacy accorded to complexity by the changing aesthetics of science.

The significance of pictoriacy was underscored by a report from a computer manufacturer; it highlighted the vast untapped potential for visualization as a channel of information transmittal. The author of the report calculated that the average human optical-brain system could assimilate two million pixels per frame at 2 and 3 bits per pixel. Seven frames per second are still distinguishable by this average human system, which therefore has a total capacity to absorb 28 to 42 million bits of information per second. If letters were represented by 7-bit characters in your brain as they are in computers, normal reading at 600 to 1,200 words per minute, with five letters per word, uses only 350 to 700 bits per second of this enormous capacity.[29] Such an estimate may sound extreme, but a good graphics display can convey truly enormous amounts of data at a glance. A group of researchers associated with Zabusky assessed the situation in the following terms:

> Looking at the printed numbers is out of the question. Our visual systems are designed to process large amounts of data most efficiently through pattern recognition; in fact, many individuals receive insight and retain concepts through seeing. We also have the ability to abstract and generalize, enabling us to compress information significantly by separating what is important from what is unimportant. In the past, the communication of scientific results was based largely on the verbal and analytical abilities of the left side of the brain. In

> the future, with the enormous amount of information thrown at us by numerical experiments, we will have to rely to a greater extent on the nonverbal and synthetic abilities of the right side of the brain.[30]

At Smarr's supercomputer facility, trained artists, cinematographers, and scientists cooperate to enhance visual comprehension of the images generated. His groups are unabashedly called "Renaissance Teams."

One result of the confluence of rapidly increasing graphics needs and an enhanced pictoriate capability will be a better understanding of the limitations of the written word and a heightened appreciation for the meanings that can be conveyed by nonverbal imagery. As we achieve greater pictoriacy, we are likely to gain new insights into what is gained and lost when literacy is introduced. We could also begin to understand more fully the role of visual communication in different cultures, including those of our own past. For example, anthropologists, historians, and scholars of literature and the arts could cooperate to comprehend the early medieval and pre-classical Greek worldviews with an enhanced sense of immediacy.[31] Looking to the future rather than the past, we may also gain new insight into the power and pitfalls of electronic visual media.

Grappling directly with nonlinearity has been made possible by numerical computer techniques, and it legitimates the aesthetic of complexity in a way that is likely to bring whole organism biology (including ecology) into broader view as a guide to understanding order in science as well as in other fields of inquiry. Since interaction and adaptation and development over time are key concepts in this form of biology, its practitioners expect nature to be full of creativity and surprises. Although they are not whole organism biologists, two physicist pioneers of nonlinear science recently displayed the mind-set I am describing:

> . . . serious models of adaptation are inevitably nonlinear. Adaptive behavior is an emergent property, which spontaneously arises through the interaction of simple components. Whether these components are neurons, amino acids, ants or bit strings, adaptation can only occur if the collective behavior of the whole is qualitatively different from that of the sum of the individual parts. This is precisely the definition of nonlinear.[32]

The authors conclude with the notion that adaptation involves an optimizing, "learning" process with dynamics on at least two time scales. Local problem-solving occurs on a fast scale (perhaps as short as the reproductive cycle), whereas system learning and creativity take place on a slower scale (as long a 10^3 or 10^9 years).[33]

Others have also stressed the role of time-dependence in nonlinear systems. Perhaps none of them has been more outspoken than Nobel laureate Ilya Prigogine. Prigogine maintains that physicists have finally "rediscovered time" and the active legacy of past experiences for inanimate as well as animate complex systems.[34] There is a tradeoff, however. He warns that modelling becomes risky because "in complex systems both the definition of entities and of the interactions among them can be modified by evolution. Not only each state of a system but also the very definition of the system as modelized is generally unstable, or at least metastable."[35] His hope is that the sciences and humanities will find common ground since he views human societies as highly sensitive complex systems in which "individual activity is not doomed to insignificance" and where "even small fluctuations may grow and change the overall structure."[36]

The humanities and the social sciences will find themselves radically affected as organic imagery intertwines with the mechanistic imagery decried by critics such as Barber to form new metaphors for defining the basic assumptions of our culture. Legitimation of complexity in mathematics and the physical sciences places a premium on understanding systems all at once, across a range of values for both parameters and dependent variables, and with limitations on universal prediction. The emerging metaphors should convey the validity of difference and variety, of creative "edge" effects, and of the strength that arises from adaptive flexibility rather than prescriptive control. These are concerns traditionally articulated among the humanities, which will acquire a powerful new vocabulary for the task.

Another far-reaching development may be a major change in our understanding of the subject-object relationship. As ultrafast, interactive computation and graphics become more widely available, and as more and more data we need to function are lodged in the machines and their programs, it will become increasingly difficult to insist upon retaining the conventional divide between subject and object. The telescope and microscope once enlarged our sense of vision, but they also encouraged us to think of ourselves as observers. The computer could have a very different effect.

A more participatory subject-object relationship would mean a transformed sense of nature and its patterns. In the future, a large portion of our "natural" reality will be entangled with the digitized, interactive world of the computer. If this reality includes expanded possibilities discovered as a result of attending to nonlinear relationships, it will undoubtedly be responsive to a more sophisticated sense of order in nature. The concept of natural law has been severely criticized by feminists on the ground that it is rooted in an overly narrow view of both nature and human beings. For example, Evelyn Fox Keller has argued:

> The concept of order, wider than law and free from its coercive, hierarchical, and centralizing implications, has the potential to expand our conception of science. Order is a category comprising patterns of organization that can be spontaneous, self-generated, *or* externally imposed; it is a larger category than law precisely to the extent that law implies external constraint . . . . A focus on order might look more to the biological sciences than to physics for its model. And within both physics and biology, priorities might be expected to shift away from hierarchical models of simple, relatively static systems toward more global and interactive models of complex dynamical systems.[37]

Such an approach would not see a jungle, for example, as a place to be feared, cleared, and controlled; on the contrary, it would regard the jungle as a seedbed of creative genetic response to the environment. It might also attract more women into mathematics and the physical sciences, at present the most "masculine" disciplines -- masculine in part because their operative assumptions tend to require the separation of the observer from the observed. How young girls respond to interactive computer graphics will be an indicator of the extent to which they are likely to participate in these fields in the future.[38] It is quite possible that the Newton of the twenty-first century will be a woman.

As an historian continually grappling with the intricacies of context and time-dependent phenomena, I find the images generated by nonlinear science to be especially thought-provoking. The complex, entangled boundary of the Mandelbrot set offers a far more satisfying image of relations among nations than does the prevalent political science "realist" concept of discrete frontiers separating the realms of autonomous nation-states. That fractal boundaries in various systems can be temporal as well as spatial implies an interesting approach to the perennial problem of periodization -- when did the "modern" world begin? When did the Renaissance occur? When did Rome "fall"? The dynamic equilibria in the transitions between "periods" of relative coherence may well reveal intriguing patterns. Shifting to deterministic chaos, the notion that memories may be represented by attractors in a dynamical system also has appeal, for history is a form of collective memory tied to the fluctuations in the experiences of each historian and each generation. "Sensitivity to initial conditions," in which arbitrarily small displacements can mean entirely different outcomes, immediately suggests the importance of individuals and accident in any sensible historical account. It also brings to mind the tensions that arise between emphasis on discontinuities in political/intellectual history and continuities in social/statistical approaches to the past. That tension is obvious in the assertions of Gertrude Himmelfarb, who argues:

> To the extent to which the political realm is more conducive to rational choice, compared with the social realm which is governed by material and economic concerns, it is in politics that the potentiality for freedom lies. This explains why social history tends to be more deterministic than political history and why political history finds a natural ally in intellectual history.[39]

For scholars, such as Himmelfarb, who see politics as choice and action at a "major" critical point, images drawn from chaos theory provide striking metaphors for the ways randomness and order can interact. For scholars and others concerned with politics as routine, daily decisions that ultimately produce important developments, nonlinear systems likewise suggest a new set of assumptions about what might be called the complexity of "minor" critical points. It is no longer necessary for historians to explain away the fact that small inputs can produce disproportionately large effects, while large-scale inputs can generate diminutive results; violation of proportionality is actually part of the natural order inherent in any interactive, nonlinear system. This is in part what Prigogine has been arguing when he sees common ground emerging between the humanities and the sciences.

Perhaps one of the most promising implications of nonlinear science is a narrowing of the gulf that so often separates persons in the arts and humanities from those in the sciences. As scientists deal increasingly with complex systems and become more amenable to an aesthetic of complexity, they will be less and less able to restrict the objects of their concern to simple systems for which idealizations or linear approximations will suffice. Some time ago, the historian Bruce Mazlish contrasted the currently prevailing basic impulses of the sciences and humanities in the terms quite relevant here:

> Science seeks to reduce matters to their simplist terms, to group such simplified phenomena under a single law, and to rid itself of all ambiguities. Its favorite mode, correspondingly, is the quantitative and precise; and its aim, generalized law. The humanities, on the other hand, wallow in ambiguities and ambivalence and, if anything, seek to pile additional meanings on an outwardly simple datum. Complexity is not only the bedevilment of the humanities, but also their hearts' secret desire. Rather than try to reduce the number of variables, humanists constantly try to increase them, sensing the interconnectedness of all things and aware of the fallacy of misplaced concreteness and the hubris of partial knowledge. The social sciences, in turn, are attracted both to the

> generalizing and simplifying aims of the natural sciences and to the value-oriented and subjective interests of the humanities.[40]

Complexity and ambiguity have long been regarded as weaknesses of the humanities, but Mazlish understands that the vision of the sciences, both physical and social, is limited. In particular, the primacy of analogy offers the clarity that resolves differences, but he argues that analogy sees with only "one eye" in a search for hidden similarities.[41] As we approach the twenty-first century, we need vision that encompasses both similarity and difference.

The quest for clarity at the cost of context has, since the seventeenth century, been a defining feature of the sciences, and consequently of western culture. Ambiguity has remained a positive abiding concern only in humanistic studies, particularly in the realms of history and literary theory.[42] The sociologist Donald Levine has claimed that a "flight from ambiguity" profoundly characterizes western society, leaving modern social scientists in particular ill-equipped to observe and represent ambiguity where it does exist, and rendering them incapable of perceiving the constructive role of ambiguity in theory and practice.[43] Simone de Beauvoir (on existential grounds) and other feminists have argued that a general intolerance of ambiguity engenders a blindness to the context of ends and to the consequences of actions.[44] Still others have focused on metaphor, myth, or irony to reawaken a sense of the imagizing mind. The literary theorist Harvey Birenbaum, for example, argues that "a myth itself is a context for insight rather than the vehicle of a message." He concludes that myths belong to an ensemble of contextual, nonlinear modes of thought associated with the integrative, spontaneous right hemisphere of the brain.[45] These are exactly the qualities of the mind elicited by "computational synergistics" and the ultrafast computer graphics advocated by Smarr, Zabusky, and other leading scientists and mathematicians.

It is ironic that a quest for ever greater precision with numerical techniques has demonstrated the limitations of the notion of idealized perfection embedded in analytical techniques, but we should be wary of thinking in ways that are too dichotomous. Irony itself is a type of "folding" along a trajectory where our actions and their consequences can seem to diverge exponentially from our intentions and expectations. We employ dichotomies in order to escape ambiguity, but the boundaries between the alternatives are frequently as complex and unresolvable as the fractal boundary between basins of attraction in the Mandelbrot set. Dichotomies are, after all, artificially imposed according to an aesthetic of simplicity that is ill-suited to the nonlinear complexities of biological, social, or cultural systems, including precisely the boundary between the sciences and the humanities. As we expand our pictoriate intuition in response to the aesthetic of complexity emerging from nonlinear science, scientists may join with humanists in recognizing ambiguity not as confusion, but as a legitimate

boundary state that offers enhanced possibilities for understanding the contextual dimensions of reality.

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Notes

[1] Some of the implications of this fact, and challenges to it presented by some of the developments discussed below, are boldly addressed by Jean-François Lyotard, *The Postmodern Condition: A Report on Knowledge* (Minneapolis: University of Minnesota Press, 1984.)

[2] Benjamin Barber, *Strong Democracy: Participatory Politics for a New Age* (Berkeley: University of California Press, 1984), 26-66.

[3] See the essays in Judith Wechsler (ed.), *On Aesthetics in Science* (Cambridge, MA: MIT Press, 1978). Observations on this point have been made by nearly every famous scientist and mathematician and inform the writings of authors as far apart on other issues as Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1962, 1970) and G.H. Hardy, *A Mathematician's Apology* (Cambridge: Cambridge University Press, 1940).

[4] The degree of the sophistication of our tools affects our "pecking order" among the sciences, which usually accords mathematics and physics positions above chemistry, followed by biology, etc. For a discussion of how misleading this can be, see F.A. Pantin, *The Relations between the Sciences* (Cambridge: Cambridge University Press, 1968).

[5] In a judicious 1940 survey of nonlinear problems faced by engineers, Theodore von Kármán felt constrained to omit turbulence, because "the study of turbulent motion has not, as yet, led to a clear mathematical formulation of the fundamental laws for the mean motion." This was a master of the field of aerodynamics and wind tunnel techniques speaking, a man who was not shy about covering many other fields. See his "The Engineer Grapples with Nonlinear Problems," *Bulletin of the American Mathematical Society* 46 (1940): 664. Zabusky (see n.9 below) specifically refers to von Kármán and this article in a special issue of *Physics Today* devoted to the new supercomputer techniques that make such problems less intractable.

[6] Larry Smarr, "An Approach to Complexity: Numerical Computations," *Science* 228 (26 April 1985): 403.

[7] *Ibid.*, 407.

[8] *Ibid.*, 407.

[9] Norman Zabusky, "Grappling with Complexity," *Physics Today* (October 1987): 25.

[10] *Ibid.*, 26.

[11] In both of these mathematical expressions, F could be some operator rather than a function, while x and y could be functions rather than variables, and the relationship would still be linear. One pair of authors distinguished linear from nonlinear operations this way: "The mathematical operations of addition, subtraction, multiplication by a constant, integration with respect to time, and differentiation with respect to time are appropriately thought of as *linear* mathematical operations. Others, such as multiplications and division of variables, raising to powers, extracting roots, coordinate transformations (including vector resolution), and integration and differentiation with respect to dependent variables (variables other than time), can be termed *nonlinear operations*." Dunstan Graham and Duane McRuer, *Analysis of Nonlinear Control Systems* (New York: Dover, 1961), 28.

[12] For example, if $F(x) = x^2$ then the equation $y = ax^2$ yields a family of parabolas, the steepness of whose sides increases as the parameter a increases.

[13] National Research Council (U.S.), Physics Survey Committee, *Scientific Interfaces and Technological Applications (Physics through the 1990's)* (Washington: National Academy Press, 1986), 132.

On computers and the latter, see Henry Petroski, "Numeracy and Literacy: The Two

Cultures and the Computer Revolution," *Virginia Quarterly Review* 61 (1985): 302-17.

[15] James Gleick, *Chaos: The Making of a New Science* (New York: Viking, 1987).

[16] Benoit Mandelbrot, "How Long is the Coast of Britain?" Statistical Self-Similarity and Fractional Dimension," *Science* 155 (1967): 636-638. See also Mandelbrot, *The Fractal Geometry of Nature* (New York: W.H. Freeman, 1977), 25-33.

[17] See Mort La Brecque, "Fractals in Physics," *Mosaic* 18 (Summer 1987): 22-41; Bruce J. West and Ary L. Goldberger, "Physiology in Fractal Dimensions," *American Scientist* 75 (July-August 1987): 354-65.

[18] This presentation of the Mandelbrot set follows that provided by Heinz-Otto Peitgen and Peter Richter, *The Beauty of Fractals* (NY, etc.: Springer Verlag, 1986), 1-18. The accompanying photographs have also been taken from this volume.

[19] John H. Hubbard of Cornell, as quoted by A.K. Dewdney, "Computer Recreations: A Computer Microscope Zooms in for a Look at the Most Complex Object in Mathematics," *Scientific American* 253 (August 1985): 16-20 (esp. 20).

[20] David C. Campbell, "Nonlinear Science, from Paradigms to Practicalities," *Los Alamos Science* 15, Special Issue (1987): 231.

[21] *Ibid.*, 233.

[22] See Celso Grebogi, Edward Ott, and James Yorke, "Chaos, Strange Attractors, and Fractal Basin Boundaries in Nonlinear Dynamics," *Science* 238 (30 October 1987): 632-38. Yorke has been responsible for a number of basic mathematical papers in the field of chaos studies, including Tien-Yien Li and James A. Yorke, "Period Three Inplies Chaos," *The American Mathematical Monthly* 82 (December 1975): 985-92. An early, seminal review article was provided by Robert M. May, "Simple Mathematical Models with Very Complicated Dynamics," *Nature* 261 (June 10 1976) 459-67.

[23] Grebogi, *et. al*, *Ibid.*, 637.

[24] Joseph Ford, quoted in Gleick, *Chaos*, 314.

[25] National Research Council (U.S.), Physics Survey Committee, *Condensed-Matter Physics* (Washington: National Academy Press, 1986), 232-33.

[26] James P. Crutchfield, J. Doyne Farmer, Norman H. Packard, and Robert Shaw, "Chaos," *Scientific American* 255 (December 1986): 46-57; the quotations appear on 53 and 56.

[27] Campbell, "Nonlinear Science," 218.

[28] Mel Berger of the University of Massachusetts, Amherst, at the Philadelphia meeting of the American Association for the Advancement of Science, May, 1986.

[29] Marvin L. Patterson, *Graphics: An Essential Addition to the Management/Computer Dialogue*, Hewlett-Packard "Productivity '80" Computer Conference and Exhibit (San Diego: Hewlett-Packard, (1980), 6-13.

[30] Karl-Heinz Winkler, *et al.*, "A Numerical Laboratory," *Physics Today* (October 1987): 32.

[31] On this point compare, for example, Eric A. Havelock, *The Literate Revolution in Greece and Its Cultural Consequences* (Princeton: Princeton University Press, 1982) with Brian Stock, *The Implications of Literacy: Written Language and Models of Interpretation in the Eleventh and Twelfth Centuries* (Princeton: Princeton University Press, 1983).

[32] J. Doyne Farmer and Norman H. Packard, "Evolution, Games, and Learning: Models for Adaptation in Machines and Nature--Introduction," *Physics* 22D (1986): vii.

[33] *Ibid.*, xi. For a fascinating view of intertwined time scales in biological systems, see Arthur Winfree, *The Geometry of Biological Time* (New York: Springer-Verlag, 1980). A very useful survey of the understanding of nonlinearity with an eye to biological systems is given by Bruce J. West, *An Essay on the Importance of Being Nonlinear* (New York: Springer-Verlag 1985).

[34] Ilya Prigogine, "The Rediscovery of Time," *Zygon* 19 (December 1984): 433-47.

[35] Ilya Prigogine and Isabelle Stengers, *Order Out of Chaos* (Toronto: Bantam, 1984), 204.

[36] *Ibid.*, 313.

[37] Evelyn Fox Keller, *Reflections on Gender and Science* (New Haven: Yale University Press, 1985), 132-34.

[38] On the differing responses of boys and girls to computer programming, see Sherry Turkle, *The Second Self: Computers and the Human Spirit* (New York: Simon and Schuster, 1984), esp. 93-136. I am aware of perceived sex differences in mathematics achievement as

measured on standardized tests. A good survey of possible reasons for this disparity is given by George M.A. Stanic, "Cultural Determinants of Sex Differences in Mathematics Achievement," a paper presented at the meeting of the American Association for the Advancement of Science, February 1988. Tests of "spatial visualization" constitute the one residual area where differences have not been satisfactorily explained. Stanic's major point is that context affects performance; competitive examinations, for example, provide an entirely different context than do cooperative learning tasks. Aspects of the testing context may well explain the lower visualization scores, a point I intend to elaborate in a later paper.

[39] Gertrude Himmelfarb, *The New History and the Old* (Cambridge: Harvard University Press, 1987), 31-32.

[40] Bruce Mazlish, "The Quality of 'The Quality of Science': An Evaluation," in *Quality in Science*, ed. by Marcel Chotkowski La Follette (Cambridge: MIT Press, 1982), 51-52.

[41] Mazlish, "Following the Sun," *The Wilson Quarterly* 4 (Autumn 1980): 90.

[42] See the classic and frequently reprinted work of William Empson, *Seven Types of Ambiguity* (London: Chatto and Windus, 1930).

[43] Donald N. Levine, *The Flight from Ambiguity* (Chicago: University of Chicago Press, 1985), 8.

[44] See Simone de Beauvoir, *The Ethics of Ambiguity* (Secaucus, NJ: Citadel Press, 1984).

[45] Harvey Birenbaum, *Myth and Mind* (Lanham, MD: University Press of America, 1988), 15-16, quotation on 37. For a balanced overview of split-brain research, see Sally P. Springer and Georg Deutsch, *Left Brain, Right Brain* (San Fransisco: W.H. Freeman, 1981).

Beyond the Transmission of Knowledge: A Vygotskian Perspective on Creativity

Vera John-Steiner

Thomas Kuhn's well-known distinction between "normal science" and "scientific revolutions" has an interesting parallel in the study of the mind. The way knowledge is transmitted from one generation to another is akin to the workings of normal science. In both cases the researcher's focus is upon known concepts, rather than on contradictory facts or ideas. In the domain of cognitive studies "normal science" provides the framework for examining the ways that novices acquire expertise, in terms of both content and strategies. When ordinary thinking is replaced by discovery, and new hypotheses are generated to accomodate anomalous and contradictory findings, a paradigm shift within a field may take place. Similarly, in the studies of the mind, we examine not only the internalization of the known, but also those human efforts that lead to discovery, creativity, and new knowledge.

Yet, while these two concerns have motivated considerable research in the growing domain of cognitive science, they receive unequal attention. The study of knowledge transmission is a lively and intriguing endeavor. The learner's mastery of intellectual skills, contents of knowledge, and productive strategies has been examined from a multiplicity of perspectives. The influence of Vygotskian theory is growing; for instance, the notion of "the zone of proximal development" has been of particular interest to students of development (Rogoff & Wertsch, 1984: Adams, 1987; Heckhausen, 1987). This work explores the relationship between beginners and more experienced learners, whether they are parents, peers, or teachers. Within the context of their interactions -- the zone of their joint activities -- the novice is cognitivel transformed into a contributing member of his or her culture.

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The related notion of "cognitive apprenticeship" is used by Vygotskian scholars as well as by researchers whose work is based upon an information-processing framework (see Collins, Brown, & Newman, 1987). The description offered by Collins and his co-workers clearly illustrates the point:

> Apprenticeship highlights methods for carrying out tasks in a domain. Apprentices learn these methods through a combination of what Lave calls observation, coaching, and practice, or what we from the teacher's point of view call modelling, coaching, and fading. (3)

The development of a theory of apprenticeship need not be limited to studies of skill-acquisition; it has equally important applications for the study of discovery thinking. Unfortunately, most students of cognition consider the exploration of discovery thinking and creativity to be of marginal interest, or they regard them as processes so complex that they lie beyond the scope of current methodological approaches. This reluctance includes the majority of scholars who are committed to the sociohistorial account of the mind as developed by Lev Vygotsky. For example, the study of creativity is not ever mentioned by Wertsch in his authoritative book, *Vygotsky and the Social Formation of the Mind* (1985).

Does the primary focus of knowledge transmission and "normal science" mean that there is no place within Vygotskian theoretical analyses to address creativity? It would be surprising indeed if the efforts of a theorist, whose initial interest involved the study of literature, had nothing to contribute in this area (see Vygotsky's *The Psychology of Art*, published decades after his death.[1]). His own early apprenticeships included a lengthy and detailed study of Shakespeare, and the text through which he received his instruction was *Hamlet*. I have described the role of a teacher from the past in *Notebooks of the Mind*:

> There is recognition of the importance of an intense and personal kinship that results when the work of another evokes a special resonance . . . Once such a bond is established, the learner explores those valued works with an absorption which is the hallmark of creative individuals. In this way, they stretch, deepen, and refresh their craft and nourish their intelligence, not only during their early years of apprenticeship, but repeatedly, throughout the many cycles of their work-lives. (54)

The construction of a systematic framework for the study of creativity is beyond the scope of a single essay. My focus in this chapter is to examine the differences between apprenticeships in "ordinary" contexts and creative

apprenticeships. In highlighting this contrast, I will also test the applicability of a Vygotskian point of view. But no coherent account of apprenticeships can be presented without reliance upon the work of a number of scholars of creativity whose work will form part of this analysis.

In our search for an education system that will meet the intellectual and humanitarian needs of students in the 21st century, we must embrace new patterns of knowledge and not allow ourselves to be defined solely in terms of what has been taught in the past. To construct educational settings which sustain both ordinary science and work which goes beyond the known, we need to know more about these differing forms of knowledge transmission and knowledge transformation.

My purpose is not to provide a comprehensive or novel definition of creativity, which is usually examined in terms of *creative products*, *creative individuals* (what distinguishes them from others in their fields), and with regard to the specification of intellectual and artistic processes that result in *creative outcomes*. My particular interest lies in the third of these concerns. Jerome Bruner's (1962) definition of creative acts as behavior that results in "effective surprise" is strikingly apt insofar as it includes both novelty and appropriateness. According to Bruner, the thought activity of greatest importance in achieving "effective surprise" is that of synthesis. He quotes the mathematician Poincaré, who, in his description of creative integration, "speaks of combinations that reveal to us unexpected kinship between . . . facts long known, but wrongly believed to be strangers to one another" (p. 19).

While the understanding of such a process is challenging, psychologists have traditionally sought to describe the creative *person*. Early research in the field relied on tests of personality, measures of value orientation, and tests of cognitive strengths and weaknesses (see Barron, 1972; MacKinnon, 1978; Taylor, 1966; Wallach & Kogan, 1965; and others). Contemporary students are interested in developmental and dynamic studies of creativity; they include students of the musically gifted (Bamberger, 1986), young artists (Getzels & Csikszentmihalyi, 1976), prodigies (Feldman, 1986), and college women (Helson, 1971, 1987). In these studies the characteristics of creative individuals are identified from a life-span perspective. The case study method, developed by Howard Gruber and his co-workers (1985a), is a good example of a dynamic approach to the study of creative cognition. The developmental theory that underlies Gruber's epistomological approach is that of Jean Piaget, whose theory has been the major influence in many of the above-mentioned holistic and dynamic approaches to the study of creativity. There is an interesting paradox in the use of a Piagetian framework in these accounts: while Gruber, Csikszentmihalyi, and Feldman stress the central role of historical and social dynamics in their explorations of the mind's extraordinary functioning, they build on a theory that accords

limited attention to these parameters.

By shifting the focus of the discussion about creativity to a Vygotskian approach applied to the role of apprenticeship in intellectual development, we emphasize social interdependence and social factors in general. Thus we may be able to identify explanatory concepts hitherto neglected or minimized in their importance.

Creative Apprenticeships

In a popular book on the networks of the mind, the neuroscientist Michael Gazzaniga (1985) wrote of "the summer that proved to be the pivotal ten weeks of my life":

> Twenty-five years ago . . . I read a most intriguing article in *Scientific American* written by my future mentor, Roger W. Sperry. I was then an undergraduate at Dartmouth College. He was one of the foremost brain scientists in the world . . . The 1960's were golden years for American science, when almost every reasonable research program could get funded. On what I thought was a long shot, I wrote Sperry for a summer job between my junior and senior years. To my surprise he wrote back . . . that the National Science Foundation had summer fellowships for the likes of me. I could not believe it, but nonetheless managed to accept the offer. (9-10)
>
> That summer in 1960 convinced me that brain science, especially in terms of behavior, would be my life's work. (25)

Vital relationships across generations and devotion to the work of one's mentor is a recurrent theme in the literature of creativity. In some instances, the apprenticeship process takes place in a face-to-face situation; in others, it may involve a distant teacher. Such a bond was described by the great Spanish 'cellist Pablo Casals to his friend, J. Ma. Corredor, who authored the book *Conversations with Casals*:

> This was the great event of my life: my father, who had already bought me a full-size 'cello, came to see me once a week [Casals was living in Barcelona at that time, away from his native village]. We used to go to the different music shops in Barcelona in search of scores of serious music for the weekly concerts of classical music, given at the Café Tost where I played solos. One day, quite by chance, I came across the *Six*

> *Suites* of Bach in one of these music shops. I was thirteen then. I wondered what could be hidden there, what mystery lay behind the words: *Six Suites for 'Cello Solo*. I did not even know they existed, neither did my teacher, and no one had ever spoken to me about them. It was the great revelation of my life. I felt immediately that it was something of exceptional importance. On the way home I hugged my treasure! I started playing them in a wonderful state of excitement, and it was only after twelve years' practice of them that I made up my mind to play them in public. (27)

What is the power of these encounters across generations? Why do creative indiciduals remember them with such intensity? Joseph Walters and Howard Gardner (1986) suggest that certain experiences trigger a recognition on the part of the gifted individual, a recognition of kinship, or bonding involvement with a major intellectual movement of his or her time. The mathematician Evariste Galois, temperamentally unsuited to formal success as a student, grasped the entire structure of elementary geometry in one reading of a geometry textbook by Legendre, himself a creative mathematician:

> Some crystallizing experiences, which we term "initial," occur early in life and signal a general affinity between an individual and some large-scale domain in his culture: An example would be Galois's discovery of the excitement involved in mathematical proof. (309)

Galois's experience of this "affective phase" produced, in the words of Walters and Gardner, a long-term change in his "concept of the domain, his performance in it, and his view of himself" (p. 309). Similarly, Stravinsky records his intense response to experiences within the domain of music: "As a child, he attended the theater weekly, and notes that he was greatly moved by the 'sound of Glinka's orchestra and the compositions of Tchaikovsky'" (*Ibid.*, p. 313). This experience moved Stravinsky, whose musical talent as a performer did not appear in childhood, to intuitively recognize his eventual career as a composer.

A different type of "crystalizing" experience is actually a "refining" experience, which Walters and Gardner characterize as occurring "well after an individual has undergone an initial attraction to a domain. In these refining cases, an individual discovers a particular instrument, style, or approach within a field to which he or she is especially attuned" (*Ibid.*, p. 309). Within the context of Gardner's theory of multiple intelligences, these encounters have value if "an individual is 'at promise' within a particular

intelligence or domain. . . They are a useful construct for explaining how certain talented individuals may first discover their area of giftedness and then proceed to achieve excellence within the field" (*Ibid.*, p.309).

From a Vygotskian point of view, these crystallizing experiences are seen as only a small part of a prolonged process of transformation from novice to experienced thinker. In an often-quoted passage, Vygotsky (1978) proposed that "what a child can do with assistance today she will be able to do by herself tomorrow" (p. 87). Similarly, the transformation of apprenticeship experiences into the novices' own structuring of thought may take place in a diversity of settings. In the creative domain, Stravinsky (1985) gave an interesting description of his own growth from cooperative endeavors to the increasing independence of a young composer when he described his own five-year composing apprenticeship with Rimsky-Korsakov:

> Once a week I took my work to him and he criticized and corrected it, giving me all the necessary explanations, and at the same time he made me analyze the form and structure of classical works. A year and a half later I began the composition of a symphony. As soon as I finished one part of a movement I used to show it to him, so that my whole work, including the instrumentation, was under his control. (Stravinsky as quoted by John-Steiner, 1985; 147)

Learning orchestration by starting with re-composing the work of an "expert " is a striking illustration of the Vygotskian notion of "the zone of proximal development." Wertsch (1985) describes it "as the dynamic region of sensitivity in which the transition from interpsychological to intrapsychological functioning can be made" (p. 67). Many other examples of this form of development are discussed in *Notebooks of the Mind*, where I draw upon journals, diaries, laboratory notebooks, and my own interviews with more than a hundred individuals from a variety of creative domains. For instance, the composer Dimitri Shostakovich, who had reorchestrated some of Mussorgsky's works, wrote: "I would recommend that all young composers make their own versions of the work of those masters from whom they want to learn" (Shostakovich as quoted by John-Steiner, 1985, p. 147). This form of creative apprenticeship is intense. There is a close, focused interaction between the two individuals. As the novice acquires his or her craft, the relationship between the two individuals shifts. During the development of the creative individual, there is a period of internalization when both the skills and the holistic vision of one's mentor are being acquired.

The transformation of novice into expert represents an area of inquiry that has recently captured the imagination of scholars in many different

disciplines. In *Mind Over Machine* (1986), for example, the philosophers Hubert Dreyfus and Stuart Dreyfus allude to five stages in skill-acquisition. They argue that expert performance is holistic, that is shows involvement, and that, as Albert Einstein has suggested, it requires intuition "supported by being sympathetically in touch with experience" (p. 41). According to them, involvement and intensity are necessary qualities of the creative apprenticeship. Their influential criticism of a purely rationalistic, rule-governed approach to problem-solving offers some important provisos concerning knowledge organization and delivery. In the concluding section of this essay, I will return to some of the issues they have raised and the implications they have for our conceptualization and planning of the university in the 21st century.

As studied by philosophers, computer scientists, psychologists, and anthropologists, apprenticeship has been defined as "the learning of skills and knowledge in the social and functional context of their use" (Collins et al., 1987, p. 1). But in spite of this awareness of the importance of apprenticeships, most actual analysis has been limited to "ordinary" apprenticeships, failing to differentiate between these and apprenticeships characterizing the construction of a creative life. In exploring the meaning of creative apprenticeships, I have drawn extensively on Howard Gruber's work, including some of his terminology (1978, 1980, 1981; Wallace & Gruber, in press). In his "evolving systems approach," Gruber expands Piaget's interactionist theory of intelligence, emphasizing the notion of a restless system, or, as Piaget phrased it:

> A system never constitutes an absolute end of a process of equilibration: fresh goals always arise from an attained equilibrium, unstable or even stable; and each result, even if more of less durable, remains pregnant with new progress. (Piaget as quoted by Gruber, 1985; 176)

The dynamics between continuity and change, the given and the new, are critical aspects in the study of discovery in thinking. How does the young person marshal the personal and social resources to remain sensitive to results "pregnant with new progress"? Gruber writes:

> Any theory of knowledge must concern itself with how novelty comes about. This question arose in the contex of genetic epistomology, in the effort to understand how one child makes something new for him or her. There is another strategy for studying the making of novelty; to look at individuals who have devoted their lives to . . . the construction of novelty, people who are consciously committed to careers in creative work. (1985a; 171)

Contrasting the study of novelty in the course of development with its role in the context of creative endeavors, Gruber highlights an important gap in cognitive research. While there are many different methods available for the study of children's rediscoveries, these tools are invariably developed and used in constrained environments. But if the study of novelty is to contribute to an exploration of discovery, one needs to go beyond the practice of psychology's "ordinary" science.

One way to accomplish such an objective is to look at developmental patterns. While Feldman evokes the effective interaction between the gifted individual and his or her social world, his theoretical framework omits the central role of social environment. Jeanne Bamberger's study of musically gifted children exemplifies such a commitment, for she has linked together experimental and observational approaches. Working with gifted young performers ranging in age from seven to eleven, she has documented how these young musicians developed mobile, inventive, multiple representations for sound, whereas musically untrained subjects opted for a single unvarying strategy. The detailed study of these patterns provided Bamberger with an important analogy that helps us understand the adolescent musician's "mid-life" crisis, when "previously confident and well-functioning performance . . . seems to break down" (p. 410). During this period of disequilibrium, as the young musician is searching for integration,

> there can be neither return to imitation and the unreflective, spontaneous "intuitions" of childhood, nor a simple "fix-up." As in the microcosm of the experimental situations, reflection that leads to disequilibrium can also be the means towards the inventions of new and more powerful understandings. Just as in other creative acts, the macro-process is one of evolution and transformation, of almost literally coming to see in a new way. (1986; 411)

In this sophisticated exploration of cognitive transformations, Bamberger joins a group of researchers working within the Piagetian tradition. David Feldman's work is also grounded in Piaget's epistemological framework, although he has expanded it in a variety of ways. In an essay entitled "Giftedness as a Developmentalist Sees It," he wrote:

> The search for explanation [of creative talent] . . . includes: qualities of the individual; propensities such as talents and personality differences; characteristics of the context within which an individual pursues mastery; characteristics of those who are critical influences on the process such as parents,

> teachers, and peers; and the state of development of all the various fields that might be mastered at a given moment in time . . . Now I grant that this expansion of inquiry brings with it many problems, not the least of which is to comprehend the various components of achievement and how they may interact . . . *The search for an explanation must go beyond the individual characteristics* [italics mine]; there have been too many examples of equally or even more gifted individuals not doing what their seemingly less gifted peers have done, to leave the search at the boundary of the individual's psyche. Whatever form such explanations eventually take, they will need to incorporate the individual, those who influence the indivudal, the social, cultural, and institutional context within which an individual is working, and, in all likelihood, historical and even evolutionary forces that impact on the environment during the period of time that an individual is developing. (1986a, pp. 291-292)

David Feldman's own work on prodigies, described in *Nature's Gambit* (1986b), illustrates what he has called "co-incidence": the powerful and effective interplay of predispositions and a finely tuned environment. In a similar vein, the psychologists Czikszentmihalyi and Robinson (1986) wrote that it is a mistake to view talent as "a naturalistic trait locked in the child's physiology" (p. 271). The argument for seeing talent as the fulfillment of a cultural potential is further elaborated as follows:

> [Talent] is not just a cognitive process but the focusing of the whole consciousness on a task; it is not a gift one has to hold to forever, because changes in the growing person's priorities, and changes in the demands of the domain and of the field, often turn gold into ashes and ashes into gold. (*Ibid.*, 283)

Some of the assumptions which govern the work of these dynamically and developmentally oriented researchers -- work in which the interdependence of social and personal factors is stressed -- also characterize a sociohistorical theory of the mind. However, Vygotsky's work, which is relevant in this context, has at best received passing mention in current analyses of giftedness and creativity. To explore the full potential of the Vygotskian framework, we must first look at one other approach to the study of creativity, namely the work of cognitive scientists who are combining information-processing and psychometric approaches.

In *Beyond IQ: A Triarchic Theory of Intelligence* (1985), Robert Sternberg gests that selective encoding, selective combinations, and selective

comparisons distinguish the performance of gifted and non-gifted subjects (p. 282). In explaining selective comparison -- or what others in the literature of creativity might describe as analogical thinking -- Sternberg gives a number of examples:

> A doctor or psychotherapist relates the current set of symptoms to previous case histories in his or her own or others' past experiences; again choosing the right precedents is essential. A famous example of an insight of selective comparison is Kekule's discovery of the structure of the benzine ring. Kekule dreamed of a snake curling back on itself and catching its tail. When he woke up, he realized that the image of the snake catching its tail was a metaphor for the structure of the benzine ring. (81)

In linking these examples and grouping them under a single category (i.e., selective comparison), Sternberg joins other scholars who rely upon a continuum of cognitive activities when studying creative cognition. Kekule's insights exemplify knowledge transformation, a process which in some cases contributes to paradigm shifts, whereas a physician engaged in diagnostic activities is applying analogical thought within an existing paradigm in his or her field of knowledge. A similar strategy is used by Chase and Simon (1973) and by others in the information-processing tradition. Yet, while achieving great precision in their specification of certain cognitive processes, many of these researchers tend to ignore differences between "ordinary" cognition -- akin to "ordinary science" -- and creative cognition.

To highlight the difference between these processes, I will draw upon several sources. These include literature on the creative personality (e.g., the work of Gough [1979], Helson [1971], MacKinnon [1978]); research on giftedness and creativity by Gruber, Feldman, Getzels, Csikszentmihalyi and Bamberger, who emphasize cognitive dialectics and the many aspects of creative equilibration; and the work on novice-expert interactions as depicted by Dreyfus and Dreyfus (1986). These differing sources of information about creative cognition are then integrated by being placed into a Vygotskian framework, by the way in which individuals within that tradition think about complex human processes. One recurrent theme within the sociocultural tradition is the attempt to differentiate among processes greatly at variance from each other -- processes like writing and speech, of the acquisition of a first language and the quite different mechanisms involved in the mastery of a second language. In following such a tradition, I will attempt to draw a distinction between two types of intellectual activities -- processes linked to paradigm elaboration versus those necessary for paradigm shift. Table 1 below describes, analytically, cognitive and personal characteristics of

TABLE 1

Thinking relevant to paradigm shift: creative cognition	***Thinking relevant to paradigm elaboration:*** ordinary cognition
1. Domain fluency: individuals have an exceptionally strong grasp of the knowledge base of their domain, beyond the mastery required for ordinary expertise (Degroot's chess masters, 1965).	1. Domain mastery: individuals are well-versed with the governing paradigms and defining concepts of their fields. They know how to use specialized resources.
2. Intense involvement -- "a passion for one's task" (Thomas Mann): in addition to self-reports by creative individuals, personality studies highlight characteristics such as artistic, complicated, courageous, emotional (Helson, 1971).	2. Strong task orientation (see skill level 3 in Dreyfus & Dreyfus): comparison subjects in studies of creative mathematicians and architects are desribed as organized, realistic, reliable (Helson, 1971).
3. Multiple perspectives (Gruber, "Productive intersection of multiple enterprises," 1981, p. 256): crucial roles of interdisciplinary approaches.	3. Thought economy: efficient application of domain-specific points of views and strategies.
4. Intuitive as well as deductive problem-solving strategies (Polya, Einstein, etc.); flexibility in strategy.	4. Sequential, rule-governed problem-solving approaches.
5. Self-knowledge (see *Notebooks of the Mind* for descriptions of creative individuals' knowing use of memory, generative and motivational approaches to sustained productivity).	5. Separation of public (work approaches) from private domains.
6. Shifting roles: collaborative periods, intense debates, exchanges, joint activities alternating with solitary work.	6. Specific role (collaborative or individual approach to work situation): stability of role over long periods.
7. Integrative view of one's work, the development of a "network of enterprises" (Gruber's concept).	7. More task than holistic orientation.

individuals inclined toward habits of thought productive of paradigm shifts.[2] In reality, the features listed are interactive and form a dynamic, functional system within each individual. Clearly, individuals vary both in degrees of creativity and in the ways their creative tendencies are woven together throughout development and expressed in their works and lives.

Do creative apprenticeships contribute to the development of domain fluency or to self-knowledge? These features of creative cognition can be nourished and sustained in fine-tuned interactions across generations. Stravinsky's lengthy apprenticeship with Rimsky-Korsakov is an example of the successful internalization of a mentor's knowledge. In recomposing and orchestrating his mentor's work, Stravinsky developed great fluency and self-confidence, increasing his willingness to start on his own creative activities.

Lengthy collaboration between more and less experienced members of a working dyad may result in the apprentice becoming too imitative.[3] Experienced mentors are aware of such a danger, and they may be able to provide a changing, dynamic interaction that enhances the apprentice's depth of exposure while encouraging him or her to develop a separate artistic (or scientific) identity. Another way the creative novice can resist the danger of becoming a "clone" is to remain open to the influence of more than one mentor or "distant teacher." Gruber (1985) describes such a process in Mozart's life:

> Recently one of my students analyzed two series of string quartets composed by Mozart, the first in 1773 when he was 17 years old and the second, begun after a lapse of 9 years, from 1782 to 1785 (Leresche, 1984). Both series were immediately preceded by the appearance of string quartets by Haydn, and both owed much musically to him. The first series are imitative, well schooled, formal and a little dull. The second series -- richer, more subtle, and more flowing -- were begun shortly after Mozart made his personal discovery of Bach, whose music he then studied with ardor. Mozart dedicated the 1782-85 quartets to Haydn, and wrote to his friend and master a letter openly acknowledging his debt, avowing that Haydn was "the father, the guide and the friend" of these pieces . . . .Thus, like other young men leaving adolescence behind, when Mozart had grown musically independent of his older model, and had time to assimilate other influences into forms that were more and more "Mozartish," then he could acknowledge his origins with gratitude. (251)

There are some intriguing suggestions about novelty and creativity in this account. One of the ways an individual scientist or artist goes beyond the

known is by synthesizing diverse influences while seeking his or her own voice. The ability to push beyond the known, or a single model or mentor, is nourished by the novice's intensity of engagement. It is this quality which sustains experimentation -- which sustains the novice's immersion in the work of a mentor as well as the work entailed in going beyond what he or she has been able to share.

The application of a Vygotskian framework to the development of creative individuals enables us to highlight certain developmental and cognitive dialectics. One of these is the transformation of joint experiences into the foundation of an individual's own creative development. Such transformations are particularly well-depicted by composers. In *Findings* (1982), Leonard Bernstein records the transforming impact of Serge Koussevitsky, his own most stimulating model:

> He taught his pupils by simply inspiring them. He taught everything through feeling, through instinct and emotion. Even the purely mechanical matter of beating time, of conducting four beats in a bar, became an *emotional* experience, instead of a mathematical one. (p. 186)

He later describes Koussevitzky as a man possessed by music, "whose possessedness came at you like cosmic rays" (p. 273). The accounts presented in this paper (and additional ones described in *Notebooks of the Mind*) provide examples of how Vygotsky's notion of "the zone of proximal development" operates in creative interactions.

A central feature in these interactions is the intensity of creative individuals. While we cannot clearly identify the sources of intensity among young men and women who commit themselves to the construction of a creative life, the ubiquity of this quality has repeatedly been noted by students of giftedness and creativity (Renzulli, 1986). In personality studies of creative adults, "the creative person's independence shows itself most clearly in situations with challenge, replete with ambiguity and puzzling complexity" (Albert & Runco, 1986, p. 339). According to this analysis, the independence of the mature creative individual seems to result in part from a productive interdependence that characterized an earlier stage in their lives. Of particular interest in this context are Ravenna Helson's (1971) findings on creative women mathematicians, who were found to be receptive to emotional stimuli while displaying intellectual direction and control as well as a need for autonomous self-direction (p. 42). Such a dynamic tension between receptivity and control may accompany the shift from collaborative to independent mastery in the course of creative apprenticeships.

In brief, I am suggesting that the integration of what Howard Gruber identified as the three sub-systems in creativity -- knowledge, purpose, and

affect -- is supported by finely-tuned, effective interactions with mentors, distant teachers, and experts in one's field. These bonds are of significance to members of both generations; they provide renewal for the more experienced member, and they enable the transformation of interpersonal experience into the full development of the self for those beginning their creative endeavors.

This point is related to a phenomenon that I have pointed out elsewhere:

> The processes of growth require resolution of the contradictory tensions between the social embeddedness of learning and the creative individual's drive toward a personal voice. When a young artist or scientist begins upon a unique path by declaring his or her identity (I am a writer, or I am a mathematician), he or she needs the assistance of others to overcome the limitations of a single view and to face public criticism or rejection. The demands of solitary work are coupled with those of participation with others in their creative fields throughout the life-span of gifted individuals. (*Notebooks*, 208)

The productive tension between social connectedness and individual focus is a recurrent theme in the study of creativity. Its role is highlighted by Vygotskian theory in which fusion, transformation, separation, and synthesis are tools of analysis for the study of complex developing processes. In this context it is interesting to note that social bonds play a significant role in the later stages of creative lives as well; intense interactions across generations are frequently followed by intense friendships, which lay the groundwork for artistic and scientific conditions that become particularly powerful during periods of paradigm shift. The Cubist painter Georges Braque described the powerful connections that linked the painters together as they struggled with their emerging concepts:

> The things that Picasso and I said to one another during those years will never be said again, and even if they were, no one would understand them any more. *It was like being roped together on a mountain*. (Braque as quoted by John-Steiner, 1987; 209)

Similarly, the twentieth-century physicists who were committed to going beyond Newtonian physics established a community that was more than collegiality.

> They debated their new ideas during long walks, while visiting each other's homes, and in letters as well as at conferences --

> exchanges described by Heisenberg and further analyzed by some historians of science. These important documents highlight the role of closely knit groups during the construction of a new framework. (John-Steiner, 1985; 209).

If such interactions are indeed important, can they be developed and sustained in the university?

Development of Creativity in the University of the Future

While universities do an adequate job of training researchers to elaborate existing paradigms, it is questionable whether they really develop and nourish the talents of those who may change them. Of course, apprenticeship learning is already part of university training, although it is not always recognized as such. It may exist as the relationship between a student working on a dissertation and his or her supervisor; between a student and his or her consultant in a clinical situation; between members of a laboratory staff and their research director. But while these are important, highly bonded relationships, we do not know much about them.

Our most effective models for creative apprenticeships have so far been drawn from artistic relationships such as those cited in this paper, most of which have existed at least in part independently of academic settings. A critical aspect of such relationships has been the shift, on the part of the novice, from assisted performance to achievements marked by increasing independence. Such a shift is particularly difficult to achieve within the current structure of graduate student supervision, where students have limited opportunity to explore interdisciplinary relationships. This potential blockage of creative development needs to be examined fully if the present discussion of apprenticeship relationship and mentoring is to be useful in envisioning the university of the future.

Such discussion is inevitably linked to the broader subject of flexibility in training. Consideration of the issues involved may be informed by the description of characteristics of creative cognition outlined in Table 1. Among the attributes of those involved in changing paradigms of thought is multiple perspectives, or the ability to see problems from a variety of points of view. This ability is linked to the productive use of interdisciplinary approaches, research areas where the search for new patterns of integration is apt to be prominent. Even a brief listing of individuals who have introduced new paradigms and thus altered the face of psychology illustrates the importance of such a claim. William James, Jean Piaget, Sigmund Freud, Karen Horney, and Lev Vygotsky all built upon their exposure to a variety of fields and integrated insights gained from multiple perspectives while moving

toward their own distinctive syntheses.

One specific example of the creative impact of working across disciplinary boundaries is illustrated by the career of the mathematician Edward Witten, whose contributions are described in a recent article, "A Theory of Everything," by K. C. Cole. He writes:

> Math -- which has to do with abstract, intangible relationships -- has always been important in physics -- which has to do with concrete forces and objects in the actual world. Witten has turned things upside down, attempting to show how physics can provide new insights into mathematics. (20)

While emphasis upon the development of an interdisciplinary imagination among future students is not a new thought, its importance is clearly demonstrated by an interactionist analysis of creativity. However, while literature on creativity has emphasized multiple perspectives and interaction across generations, these have not been seen as central in previous analyses. In this paper, their roles have been more clearly delineated, and Vygotskian theory has been extended through its application to creative endeavors.

This chapter presents one exercise in an ongoing application of Vygotskian concepts to creative apprenticeship situations. It is my hope that, by utilizing this framework to explore such apprenticeships both inside and outside academia, we will find ways to nourish rather than extinguish "the passion for one's task" of those members of future generations who yearn toward a life of consequence, a life devoted to creative possibilities.

Notes

[1] L.S. Vygotsky was born on November 17, 1896, in Belorussia. He studied medicine and law as well as psychology, philosophy, and literature in Moscow. He taught in Gomel, and established a psychological laboratory before moving to Moscow in 1927. *The Psychology of Art* was the basis of his dissertation; he completed it in 1925. Between 1925, the year he became well-known as a psychologist, and 1935, the year of his death from tuberculosis, he produced over 180 pieces of work. Many of these were only published in his collected work, 1982-1984, as he was the target of criticism between 1936 and 1953. The publication of his works was resumed in 1956. *Thought and Language*, MIT Press, 1962 and 1986, and *Mind in Society*, Harvard University Press, 1978, are his works best known by English-speaking readers.

[2]. The list of characteristics presented in Table 1 was jointly constructed by my students and myself in a creative thinking seminar at UC Berkeley in the early spring of 1988. The construction and presentation of a contrastive list should be seen as an expository device only.

[3]. This is a point that Professor Jonas Langer raised with me. I would like to thank him for his perceptiveness.

Works Cited

Adams, A. K. *Vygotskian Approaches to Semantic Development: Implications for Design and Analysis*. Paper presented at the Fourth International Congress for the Study of Child Language, as part of the workshop, "Vygotskian Approaches to Child Language Research," Lund, Sweden: July, 1987.

Albert, R. S., & Runco. M. "The Achievement of Eminence: A model based on a Longitudinal Study of Exceptionally Gifted Boys and Their Families." In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of Giftedness*. New York: Cambridge University Press, 1986.

Bamberger, J. "Cognitive Issues in the Development of Musically Gifted Children." In R. J. Sternberg & J. E. Davidson, *Conceptions of Giftedness*. New York: Cambridge University Press, 1986.

Barron, F. X. *Artists in the Making*. New York: Seminar Press, 1972.

Berger, J. *The Look of Things: Essays*. Edited by Nikos Stangos. New York: Viking, 1971.

Bernstein, L. *Findings*. New York: Simon and Schuster, 1982.

Bruner, J. *On Knowing: Essays for the Left Hand* (expanded ed.). Cambridge, MA: Belknap Press of Harvard University Press, 1979.

Casals, P. *Conversations with Casals* by J. Ma. Corredor. Translated from the French by Andre Mangeot. New York: Dutton, 1957.

Chase, W. G., & Simon, A. "The Mind's Eye in Chess." In W. G. Chase (Ed.), *Visual Information Processing*. New York: Academic Press, 1973.

Cole, K. C. "A Theory of Everything." *New York Times*, Sec. 6, p. 20, October 18, 1987.

Collins, A., Brown, J. S., & Newman, S. E. "Cognitive Apprenticeship: Teaching the Craft of Reading, Writing, and Mathematics." In L. Rosnick, *Cognition and Instruction: Issues and Agendas*. Hillsdale, NJ: Erlbaum, 1987.

Czikszentmihalyi, M., & Robinson, R. E. "Culture, Time, and the Development of Talent." In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of Giftedness*. New York: Cambridge University Press, 1986.

De Groot, A. D. *Thought and Choice in Chess*. The Hague: Mouton & Co., 1965.

Dreyfus, H. L., & Dreyfus, S. E. *Mind over Machine: The Power of Human Intuition and Expertise in the Era of the Computer*. New York: Free Press, 1986.

Feldman, D. H. "Giftedness as a Developmentalist Sees It." In R. J. Sternberg & J.E. Davidson (Eds.), *Conceptions of Giftedness*. New York: Cambridge University Press, 1986a.

Feldman, D. H. *Nature's Gambit: Child Prodigies and the Development of Human Potential*. New York: Basic Books, 1986b.

Gazzaniga, M. S. *The Social Brain: Discovering the Networks of the Mind*. New York: Basic Books, 1985.

Getzels, J. W., & Csikszentmihalyi, M. *The Creative Vision: A Longitudinal Study of Problem Finding in Art*. New York: Wiley, 1976.

Gough, H. G. "A Creative Personality Scale for the Adjective Check List." *Journal of Personality and Social Psychology*, 37, 1398-1405, 1979.

Gruber, H. E. "Darwin's 'Tree of Nature' and Other Images of Wide Scope." In J. Wechsler (Ed.), *On Aesthetics in Science*. Cambridge, MA: The M.I.T. Press, 1978.

Gruber, H. E. "'And the Bush Was Not Consumed.' The Evolving Systems Approach to Creative Work." In S. Modgil & C. Modgil (Eds.), *Toward a Theory of Psychological Development*. Windsor, England: NFER Press, 1980.

Gruber, H. E. *Darwin on Man: A Psychological Study of Scientific Creativity* (2nd ed.). University of Chicago Press, 1981.

Gruber, H. E. "From Epistemic Subject to Unique Creative Person at Work." *Archives de Psychologie*, 53, 167-185, 1985a.

Gruber, H. E. "Giftedness and Morality: Creativity and Human Survival." In F. D. Horowitz & M. O'Brien (Eds.), *The Gifted and the Talented: A Developmental Perspective*. Washington, D.C.: American Psychological Association, 1985b.

Heckhausen, J. "Balancing for Weakness and Challenging Developmental Potential: A

Longitudinal Study of Mother-Infant Dyads in Apprenticeship Interactions." *Developmental Psychology*, 23(6), 762-770, 1987.

Helson, R. "Women Mathematicians and the Creative Personality." *Journal of Coiunseling and Clinical Psychology*, 36(2), 210-220, 1971.

Helson, R. "Which of Those Young Women with Creative Potential Became Productive? II. From College to Midlife." *Perspectives in Personality: Theory, Measurement and Interpersonal Dynamics*, 2 [Annual], 51-92. Greenwich, CT: JAI Press, 1987.

John-Steiner, V. *Notebooks of the Mind: Explorations of Thinking*. New York: Harper & Row/Perennial Library, 1987.

Kuhn, T. S. *The Structure of Scientific Revolutions* (2d ed., enl.). Chicago: University of Chicago Press, 1970.

MacKinnon, D. W. *In Search of Human Effectiveness*. Buffalo: Creative Education Foundation, 1978.

Renzulli, J. S. "The Three-Ring Conception of Giftedness: A Developmental Model for Creative Productivity." In R. J. Sternberg & J. E. Davidson (Eds.), *Conceptions of Giftedness*. New York: Cambridge University Press, 1986.

Rogoff, B., & Wertsch, J. V. (Eds.). "Children's Learning in the 'Zone of Proximal Development.'" *New Directions for Child Development* (Vol. 23). San Francisco: Jossey-Bass, 1984.

Sternberg, R. J. *Beyond IQ: A Triarchic Theory of Intelligence*. New York: Cambridge University Press, 1985.

Taylor, C. W. *Creativity: Progress and Potential*. New York: McGraw-Hill, 1964.

Vygotsky, L. S. *Mind in Society: The Development of the Higher Psychological Processes*. Cambridge, MA: Harvard University Press, 1978.

Wallace, D. B., & Gruber, H. E. (Eds.). *Creative People at Work*. New York: Oxford University Press, [in press].

Wallach, M. A., & Kogan, N. "A New Look at the Creativity-Intelligence Distinction." *Journal of Personality*, 33, 348-369, 1965.

Walters, J. & Gardner, H. "The Crystallizing Experience: Discovering an Intellectual Gift.": In R. J. Sterberg & J. E. Davidson (Eds.), *Conceptions of Giftedness*. New York: Cambridge University Press, 1986.

Wertsch, J. V. *Vygotsky and the Social Formation of Mind*. Cambridge, MA: Harvard University Press, 1985.

Creativity as a Distributed Function

Bruce West and Jonas Salk

Recent research suggests that human creativity might best be characterized as a multilevel organizational process which shares a joint inheritance of genetic and cultural information. The organizational structure of the creative process may well mimic the neurobiological architecture of the organism. This view of the relationship between the structure of the organism and the way in which creativity functions is compatible with a perspective that has been developing in the physical and biological sciences over the past decade. This perception has emerged from the recognition that many natural phenomena are the local consequences of the activity of a distributed system.

As an example, a drought may be completely independent of local conditions, but it is always a consequence of worldwide weather patterns. Thus, the location and duration of a drought may be determined by conditions that prevail thousands of kilometers from the site of the drought. From satellite pictures of the globe we understand the interconnectedness of weather patterns, even if we cannot predict with any certainty the pattern of change for periods longer than two days. Prior to television it was difficult for the nonspecialist to appreciate the global dynamics of weather patterns. The Farmer's Almanac was popular because it "predicted" the weather a year in advance, without any consideration for meteorological dynamics. Now that we appreciate the interrelationship between local weather and global atmospheric dynamics, we are less likely to plan our decisions according to the Farmer's Almanac.

One encounters similar limitations with any Farmer's Almanac of the psyche. Static impressions of the way the creative process works are inappropriate; the dynamics must be considered globally in scope rather than

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locally. The process of creativity in an individual is an overall function of the species and cannot be said to reside in any one place or region, but is distributed throughout the system. A distributed organization is unlike a hierarchical organization. In the latter, directives in the form of information pulses are initiated at the top of the hierarchy and feedback loops keep the top informed of the behavior of the system. It is implicit in such a structure that decisions affecting the overall system can be made only at the top. In contrast, in a distributed system there is no top. All elements of the system influence all others, either directly or through some intermediary; there is no decision center. Such a model would imply that a manifestation of the creative process may arise spontaneously at any location or level of the hierarchy.

The notion of spontaneous creativity implies a certain unpredictability in the process, not unlike the limited predictability of the weather. However, unpredictability does not imply complete randomness. We can envision a system dynamics that would enhance or suppress spontaneous creativity depending on where in the distributed system the burst occurs. It is also possible that such a burst may even depend on the overall state of the system. Such a model would suggest that creativity can be elicited and the individual can be prepared to exploit aberrant thoughts and impressions that are normally systematically suppressed since they may have no apparent immediate utility. The exercising of these irregularities is a form of play; creativity along with play is usually observed in the developing child, but it is often suppressed in the course of maturation and in the adult.

If one considers the hypothesis that the creative process reflects the neurobiological architecture, then one may extend the hypothesis to reflect a similar structuring of social organizations and assume that an optimal social organization would reflect this architecture. However, governments, bureaucracies and other similar vertical hierarchies do not have an optimal structure in this regard, although it is also true that such entities are not particularly creative; by contrast, social organizations that have a distributed structure and a minimum of administrative organization do seem to foster creativity. Some organizations, as in the scientific community, have such an effect through the development and maintenance of channels of communication in meetings, journals, awards, etc. One indication of the creativity of the members of these organizations is their productivity. One measure of productivity, and indirectly a measure of creativity, is the number of papers published in a given interval of time. It has been shown that the distribution of the number of scientists publishing a given number of papers is in accordance with an inverse power-law distribution. This implies that the process by which a scientific paper reaches publication is complex and contingent on the completion of many interacting factors that are distributed in space and time. It also implies that many more scientists publish a large

number of papers than one would have predicted from a vertical hierarchy model. This is due to the fact that the ideas contained in the separate papers are not altogether independent. Moreover, not only do ideas appearing in earlier papers affect those in subsequent publications, but a new idea often affects previous observations, the significance of which could not be fully appreciated until seen in a new light.

The writing of a scholarly paper and its expansion into a journal symposium provides a good example of this kind of a distributed process. A group of individuals are exposed to the paper. They then offer their observations; in the process, they develop new perceptions and alter old ones. In due course, a common perception of the creative mind (as seen from the proposed evolutionary perspective) may emerge. A group of minds that focus on a paper about the creative mind, for example, and on an evolutionary approach to discovery and innovation, may well be serving the evolutionary process itself. Such an experiment can integrate diverse perceptions in the minds of individuals and suggest new ways of applying this process to still other questions of human interest and concern. A multifaceted concept may crystallize in a way that can be repeated; however, the product of this process will not be reproducible, just as the weather is not reproducible. The process as well as the discoveries made during the course of it can provide each participant with the opportunity to experience the creative process directly.

Affected by its own products just as two or more interactive creative minds are affected, the individual creative mind actually reflects the pattern of coevolution that is seen throughout nature. The creative mind and its products may be seen as separate elements in a dynamic, interactive, asymmetric, binary relationship. The mind may also be seen as a unit made up of two interactive distributed functions that may be referred to as intuition and reason. The brain, with its right and left hemispheres, can also be seen as the binary structure for the functioning mind with its cofunctioning intuition and reason.

The schemata presented in Figures 1 and 2 suggest a number of other cofunctioning or coevolutionary relationships in addition to that of gene culture. These are seen in the units of order at all levels of complexity which appear to be vertically homologous to all others. It is as if the fundamental unit of order in the evolutionary scheme of things is a binary relationship between two distributed functions. The process of evolution itself is, in effect, a process of coevolution in which the two elements in the relationship at each level of increasing complexity result in the emergence of new properties and new structures. These then enter into similar relationships, vertically as well as horizontally, very much like what is seen biologically, sociobiologically, and in the human realm, (i.e., metabiologically and iometabiologically).

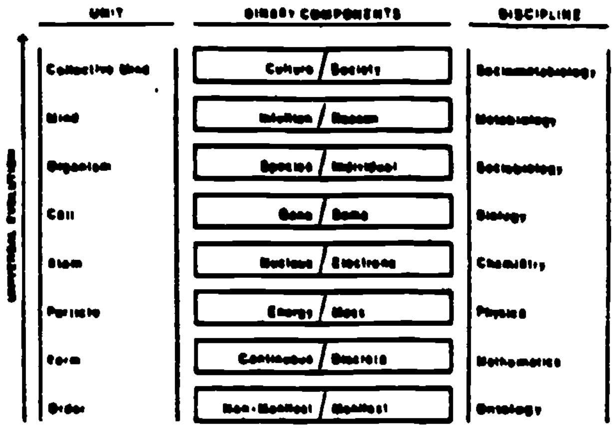

__Figure 1__: Anatomy of order. This diagram suggests that a basic pattern of order exists at all levels of evolutionary complexity as seen in the binary relationship of the elements of each unit of order. The disciplines concerned with each level are as here suggested. (Reprinted from J. Salk, 1985.)

Figure 1

UNIVERSAL EVOLUTION

	PREBIOLOGICAL EVOLUTION	BIOLOGICAL EVOLUTION	METABIOLOGICAL EVOLUTION
EMERGENCE	MATTER	LIFE	CONSCIOUSNESS
UNIT	ATOM	CELL	MIND
COMPONENTS	NUCLEUS / ELECTRONS	GENE / SOMA	INTUITION / REASON
ATTRIBUTES	INTERACTION	PROCREATION	CREATIVITY
DETERMINANTS	PROBABILITY	NECESSITY	CHOICE

__Figure 2__: Matrix of fundamental evolutionary relationships. This matrix suggests the incorporation of previous phases of evolutionary complexity into the next higher level and the later emergence of what was implicit in previously existing forms. This suggests that in the course of universal evolution life emerged from matter, and consciousness from life. The fundamental units of order in the three phases of evolution are atom, cell, and mind. Their binary components are nucleus/electrons, gene/soma, and intuition/reason. The attributes for perpetuation at each stage are interaction, procreation, and creativity. The critical determinants of evolution are probability, necessity, and choice, respectively. (Reprinted from J. Salk, 1985.)

Figure 2

Thus, if the pattern of coevolution exists throughout nature, it suggests how a process that operated between genes and culture, between genes and discoveries, began with the process of evolution and will continue without end in the evolution of diversity in the functioning of the creative mind. The schemata in Figures 1 and 2 suggest a way of seeing the creative mind (as well as discovery and innovation) within the continuity of a process of universal evolution, viewed as a distributed, dynamically interactive process that has reached its highest level of complexity in the creative mind.

Works Cited

Salk, Jonas. *Anatomy of Reality: Merging of Intuition and Reason*. 1983; rpt. New York: Praeger, 1985.

West, Bruce J. *An Essay on the Importance of Being Nonlinear*. Berlin and New York: Springer-Verlag, 1986.

A Systems Overview of the University in Society

Howard T. Odum

In our society, universities are both a flowering of civilization and means for driving economic production and consumption. But do we understand enough about maintaining knowledge to keep universities vital in times of declining resources ahead? In this essay, we consider some new ways of measuring knowledge and the products of universities. Systems models are used to overview the role of information and universities in society, the patterns within a university, and their place in the general hierarchy of nature. A scientific-based measure of value to society, EMERGY, spelled with an "M" is used to consider university contributions. A new kind of general education is suggested for keeping a technological society stable.

First, we shall consider diagrams for representing models of information, universities, and society.

Systems Diagrams

Systems diagrams are models that simplify complex phenomena in the same way that the human mind often does, by aggregating a whole into a few larger components. For example, Figure 1 shows the role of the university and information in the larger system of society. It shows the position of universities receiving the convergence of products and feeding back outputs in service of society.

The symbols of the diagrammatic language are given in Figure 2. To construct a systems diagram like that in Figure 1, a system boundary is defined first and represented by the rectangular frame. Outside influences are "sources" represented with circles. Inside components, each with a separate symbol are: Producer units (thumb-shaped), consumption units

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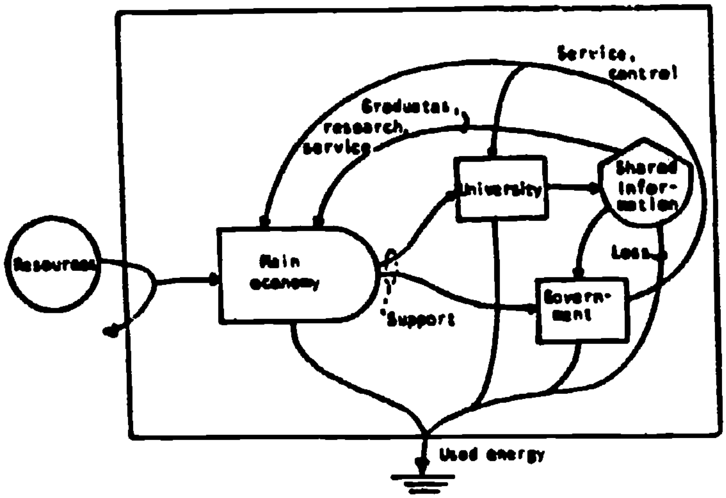

Figure 1. Diagram of the position of universities and shared information in the system of humanity and nature.

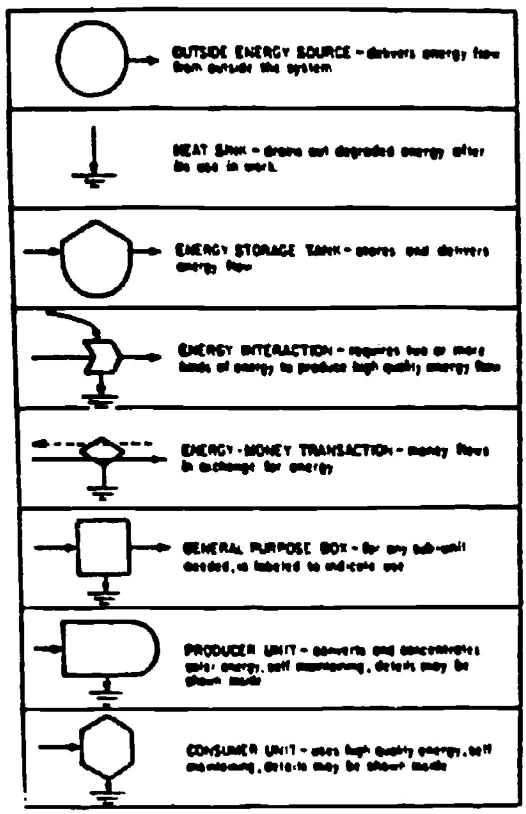

Figure 2. Symbols used to diagram systems relationships, energy flows, and hierarchy.

(hexagon-shaped), and miscellaneous (box-shaped). Where flows and forces add or diverge, lines are shown converging or diverging. Where flows and forces interact as necessary requirements of an output, the intersection is represented by an interaction production symbol (pointed block).

The symbols in the diagrams have mathematical equivalents, and the network shown has an equivalent set of equations. These equations are used in microcomputer programs to simulate system behavior. Whenever the configurations of a diagram are basic designs that have been studied and simulated before, inferences about the future performance may be suggested by inspection of the diagrams. For example, Figure 1 has autocatalytic feedback loops so that each product of transformation processes (pathways going to the right), such as information, feeds back to amplify, control, and reinforce the production processes on the left. As such systems grow and level off depending on the available resources, they may oscillate with an interval dependent on the size of the storages on the right. For more details on systems and simulation, see previous books and papers (Odum and Odum, 1982; Odum, 1971, 1983).

Hierarchies

With patterns shown in Figure 3, most if not all systems are hierarchical. Products of small units are converged and transformed to products of higher quality. These have the capability of stimulating the system when fed back to control the smaller elements of the system. As drawn, items to the left are numerous, small, rapidly turning over, whereas items to the right are fewer, larger, have large territories, are long lived, and have greater effects.

The diagram of society and the university in Figure 1 represents hierarchical positions by position on the paper from left to right. Many people and processes on the left converge their outputs in successive transformations that support the university, generating information that is high in the hierarchy of the system of society (Odum, 1983, 1987).

EMERGY and University Evaluation

A new measure, EMERGY, spelled with an "M", puts all kinds of inputs, resources, materials, energy, information, etc. on a common basis, one to which the real economic product is proportional. The solar energy required to develop a product or service is its solar EMERGY, measured in emjoules (Odum, 1985; Scienceman, 1987).

The theory says that items with large energy requirements will not be long retained by a successful economy if their effects are not commensurate with resources used. Our society is in the process of discarding some of the large resource-using experiments that are not feeding back in proportion. In other

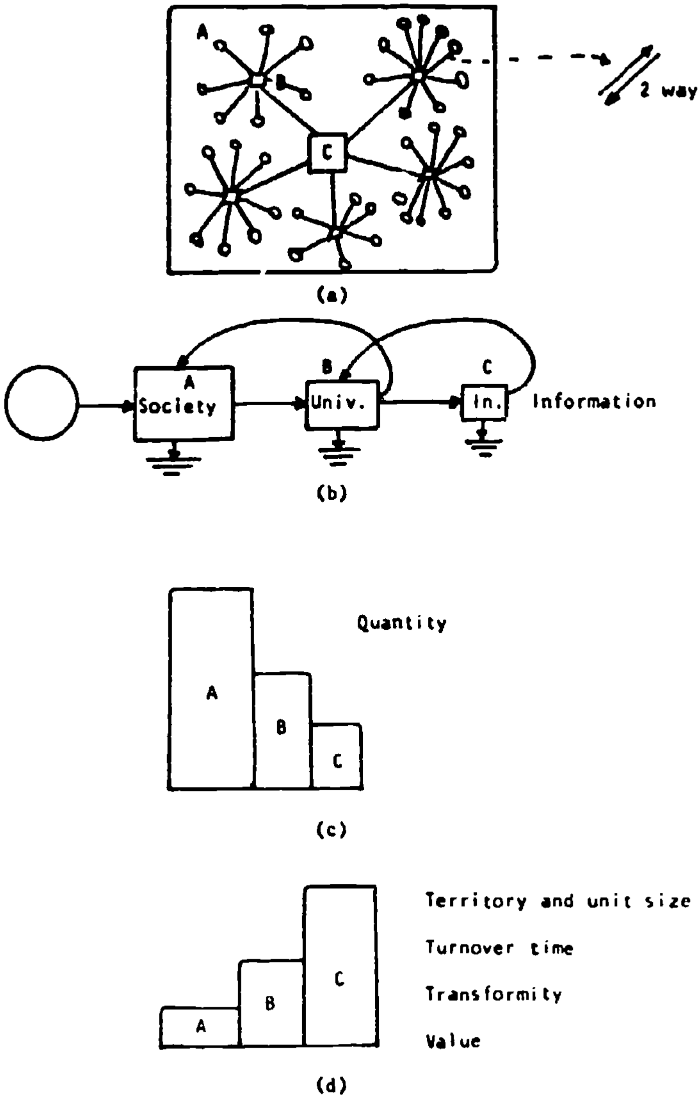

Figure 3. Ways of representing a hierarchically organized system, A to B to C. (a) Spatial pattern with each line representing a converging flow of resources and a diverging return of controls and valuable materials; (b) energy systems diagram; (c) bar graph of the energy flow at each level of the hierarchy; (d) bar graph of the solar transformity at each level of the hierarchy.

words, among tested patterns that endure, useful effects tend to be in proportion to the EMERGY that was used to make them. Effects are proportional to requirement, after failures are eliminated. Consequently, resources of different kinds can be placed on a similar basis of economic contribution by evaluating their solar EMERGY.

The total solar EMERGY flow into a university includes environmental resources, fuels, imported goods and services, information inflows, books, etc., as diagrammed in Figures 4 and 5. An EMERGY evaluation of a university is given in Table 1.

A university may be deemed beneficial if it maximizes its contribution to society and in turn receives back contributions so the two are mutually reinforcing. Guidelines for performance of a university are evaluated so as to maximize society's EMERGY. The concept of maximum EMERGY use is a refinement of the older concept, sometimes called the "maximum power principle" (Boltzmann, 1886; Lotka, 1924). As used here, the university designs that evolve are those that cause the whole system of humanity and nature to maximize its EMERGY use.

The resources at one hierarchical level required to operate a unit at another level can be evaluated with EMERGY. A major question is how much resource (expressed as solar EMERGY) is required to maintain knowledge now and in the future.

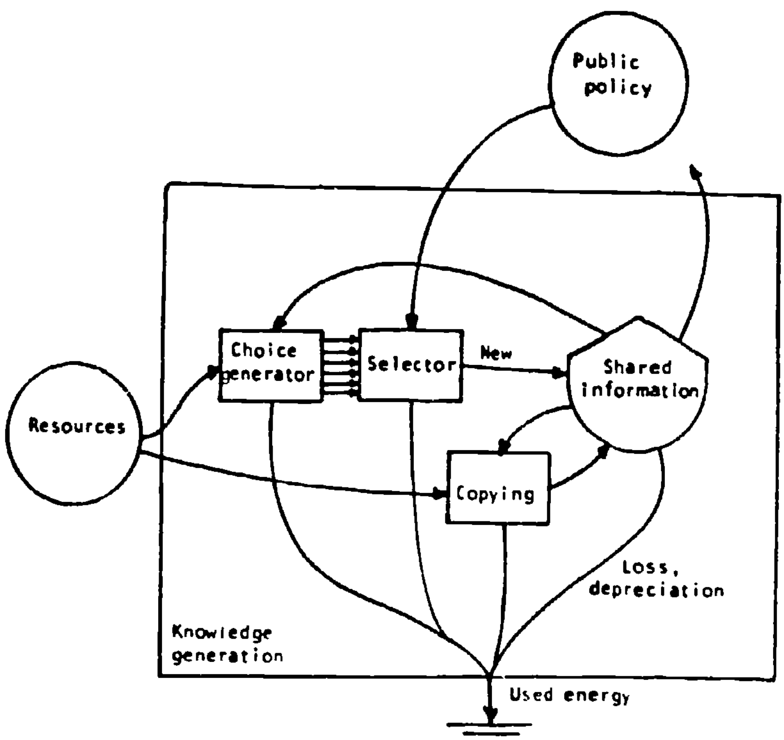

Figure 4. The generation and maintenance of information.

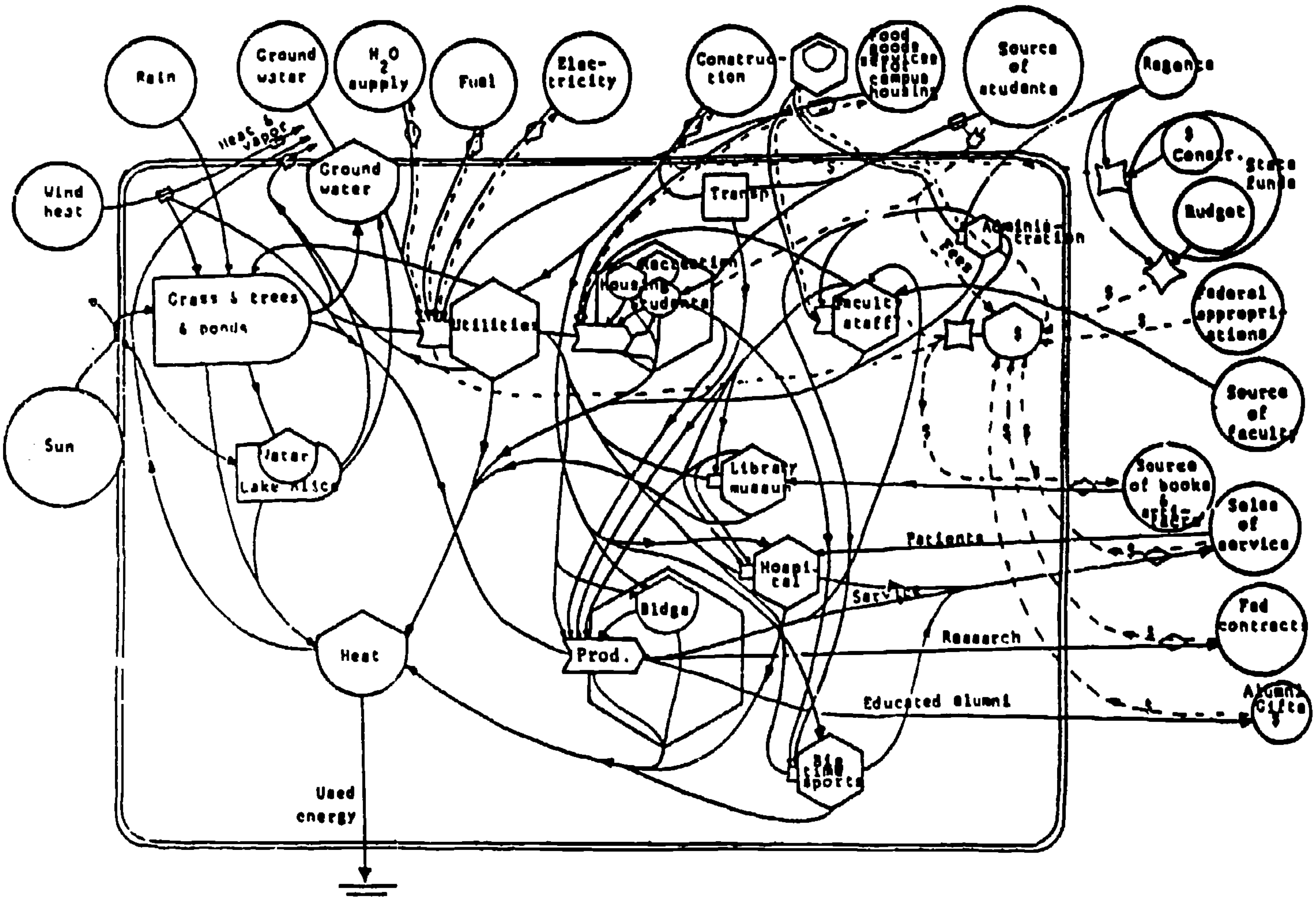

Figure 5. Energy systems diagram of the University of Florida (Odum, Gayle, Brown, 1978).

Table 1

Preliminary EMERGY Evaluation of University Inputs

University of Florida, Gainesville, 1977-78

Item	EMERGY E19 sej/yr	Macroeconomic Value (1) Million $/yr
Environmental inputs, sun, wind, rain (2)	0.076	0.26
Fuels, gasoline, water, electricity		
Emergy content (3)	22.8	75.9
Paid services (4)	6.4	21.2
Plant, administration (Services) (4)	8.7	29.0
Students		
EMERGY use from prior education (6)	83.3	278.
Paid support of students (4)	50.2	167.
Library Books (7)		
Costs of Replacing copies (4)	0.53	1.8
Operation (4)	1.45	4.8
Faculty		
EMERGY of knowledge used (5)	124.	414.
Paid services (4)	56.	187.
Construction to maintain and replace structure		
EMERGY in new building	0.78	2.6
Paid Services (4)	4.66	15.5
Sum of inputs to university production	358.896	1197.06

sej = solar emjoules (solar energy required to generate the item)

(1) Annual solar EMERGY use divided by 3 E12 solar emjoules per dollar.
(2) Energies used were multiplied by their respective solar transformities to obtain the rates of solar EMERGY use. The largest of the three is used, since they are all by-products of the same global solar EMERGY.
(3) Each type of energy used (in joules per year) was multiplied by its solar transformity (solar emjoules per joule) to obtain solar EMERGY use per year.
(4) Where an input is paid for with money, dollars paid are multiplied by the 1977 solar EMERGY per dollar to obtain the solar EMERGY contributions of people (labor, services, prior services in goods, etc).
(5) The contributions of knowledge by faculty from their information storages were evaluated by multiplying hours of intellectual efforts by metabolic energy per hour, by the solar transformity (solar emjoules per joule) of the appropriate level of knowledge.
(6) This line contains the EMERGY of information in the students that they contribute to the university process from their prior education. The number of students was multiplied by the hours of intellectual activity, by the metabolic energy per hour, and byu the solar transformity of the knowledge level in students entering the university.
(7) Library books are an information storage that is maintained by replacing old copies with new ones, a process that uses EMERGY of paper and human services. The much larger EMERGY of the first (or last) copy is what was required to generate the original book manuscript, but this is a property of the larger world information storage and is not included in this table.
(8) New square feet were multiplied by weight per square feet and by solar transformity of cement.

Hierarchical Position and Solar Transformity

Another property of hierarchies is "solar transformity". The solar EMERGY required to produce one joule of a product is the solar TRANSFORMITY of that product. The higher the position in the energy hierarchy (the further to the right on the system diagram), the less energy there is (Figure 3c), but the higher is the solar transformity (Figure 3d). Solar transformity is a quantitative measure of the position of items and processes in the hierarchy of the earth. It is a measure of quality.

Information and knowledge are a main part universities. Only small amounts of energy are associated with the information in the brain, in library books, in computers, in genes, etc., but the solar transformity of information is very high. In other words, information is at a high level of the hierarchy of components of our system. It requires much EMERGY for its development and maintenance. Therefore information is to the right in the energy systems diagrams such as Figure 1.

As an information processor, the university is also high in the hierarchy of social institutions (Figure 1), requiring a broad base of support from the processes, people, and institutions at lower levels (further to the left in the diagram). Thus, much of the solar EMERGY budget of the whole society is also required for the university, standing as it does at the top of the tree. Products of the university -- educated graduates, results of new research, and high technology services -- have high solar transformity.

The EMERGY of Information and Shared Knowledge

Universities produce information in the form of educated students, new science, new literature, new art, and new concepts. What are some of the properties of information? As Figure 4 shows, information is a result of a production process and may be evaluated by summing the EMERGY of the inputs.

One of the main roles of universities is creative in developing ideas. However, information which has not been through processes of organizing, selecting, and testing for utility may have had little effort invested and usually is not very valuable. With discussions, experiments, statistics and seminars, universities do preliminary testing and selecting research on the new information so that what survives this process is more valuable.

After that, much more trial and error work is required from the larger system of society until something useful to that system may result. As diagrammed in Figure 1, products generated by the universities are considered and selected by the public through its government, its industries, or fads of the media. The selective work by the larger system is a main source of the EMERGY in useful information production.

Even more resources are involved in duplicating information and arranging for its use by the whole society. When functional information has been widely established it may be called SHARED INFORMATION. Such information has much higher transformity (Emergy per unit energy), and in its use has a much greater power to control and amplify actions of large segments of society as it is fed back (Figure 1).

Depreciation and Maintenance of Knowledge

Information may be characterized as something that is easier to copy than to generate anew. EMERGY inputs for copying information are much less than that required to generate the information initially. Since information can only be carried by some physical memory device more concentrated than the environment, it has some energy content. Information storage is thus subject to the deterioration and depreciation of its medium of storage, usually referred to as Second Law depreciation. Hence, information must be continually recopied and errors eliminated by testing. In other words, it takes resources to maintain information with an active support process. However, the EMERGY for a copy is much less than that for the first (or last) copy in existence.

Figure 4 summarizes what is required to generate and maintain information and its role in a system. Since the carriers of information are continually lost by depreciation, development of errors, forgetting, and dispersal, information must be periodically copied and restored to maintain it.

The depreciation rate is that of the information carrier and depends on the size of the storages. Small things erode faster and have to be replaced sooner. When miniaturized, more information can be stored, but the depreciation rate is larger as the size of the information storage is reduced to the same scale as the blemishes developing in the carrier material. However, with shared information, the loss of one unit is less important and can be easily replaced by duplication from another copy.

A main function of universities is knowledge maintenance where its people reproduce information in books, in students, and in other users in society. New information is developed in universities and other institutions, subjected to choice by public process, with the consensus items put into general education, becoming shared information (Figure 4).

Hierarchical Position and University Roles

Emergy evaluations give us some insights on the University's position in the hierarchy of society. To be harmonious, university operations must all roles appropriate to the position in the the hierarchy.

As the choice generator of society, universities need high diversity, flexibility, and as much freedom as possible. Pressures from administrators to channel faculty and student efforts into particular directions or to work on what has available monies is contrary to the needs of society. Much of the public support is short term, since governments are in power for only a few years. Universities need to do what is being neglected by public agencies. The institution that has the means to work on the long range questions and things that will be needed later is the university.

Being a long-term unit high in the hierarchy with a large territory of support means a role and responsibility for a large territory. Universities, in some of their research and service responsibilities, have the same scale of operation as in governments. Some world class universities have world-scale responsibilities. Some difficulties between universities and their public support come from public misunderstanding of universities' leadership role as society's creative generator.

Student Transformation

Students arriving at a university have short attention spans, smaller territories of interest, and are low in hierarchical position. Little wonder that their evocations, recreations, and interests are often shallow. They don't initially understand the leadership roles of the university.

Part of the teaching role is expanding horizons, attention spans, and interests of students so that by the time they graduate they can participate at a higher level. University professional curricula which omit general educational objectives may be limiting the future developments of their graduates.

In other words, a main purpose of university teaching is moving students up the hierarchy as fast as possible, teaching the most capable to reach for the greater scale of responsibilities. In general, earnings of graduates will be in proportion to the position of their jobs in the hierarchy of society.

Structure and Process of the University

In the overview of society in Figure 2 the university is represented as a single box. In Figure 5 the details within this box are shown; main components and processes of a university are diagrammed. The systems view shows how such raw inputs as food and electricity are transformed into information, education, research and service. The diagram has various storages such as library, building assets, and knowledge in the minds of its faculties. The main function of the university is making its products.

Production by a University

The production by a University of new information, of educated students and special services for society is generated by the combination of necessary ingredients in the production function of Figure 5, enlarged in Figure 6. The inputs are arranged from left to right by the position of the ingredients in the hierarchy (in order of their solar transformity).

The items on the left are used in quantity, although each unity represents less earth resource in its formation. Items on the right are less common and each unit represents a large prior investment of work by nature and society. In other words, they are arranged from left to right in the order of their value to the system. It may be reasoned that functions are appropriate for a university if their effects are commensurate with the resources used in their formation. The items on the right control those on the left.

Ultimately delivered by nature and society, the total resources contributing to the university products may be evaluated as the sum of the EMERGY of the independent inputs. Requiring so many valuable ingredients, the products of a university are high in EMERGY.

When preliminary evaluation was made of these inputs for the University of Florida, we were surprised to find that the second highest EMERGY ingredient was in the students entering the system. Faculty have long known that what is possible in their performance is dependent on the quality of students.

University Contributions

Table 1 shows main macroeconomic values contributed are faculty, information in students as they enter, and then the energy sources. The ratio of macroeconomic value obtained for that spent is: students, 2.7; faculty, 3.2; fuels, etc., 3.5; university whole, 3.0. In other words, university performance is a hidden EMERGY contributor. The university is three times more important to the state economy than might be inferred from the annual dollar budget. Information is passed along and new information generated that represents the hierarchical culmination of the whole country's work, but only part of this is mediated by the money paid to support the students and faculties.

Information from prior education in students and in faculty ($692 million macroeconomic value) is 57% of the total EMERGY-based input. From previous analyses of the state of Florida (Odum et al, 1987), the total EMERGY use in 1979 was 3820 E 20 solar emjoules per year (127 billion dollars per year in macroeconomic value). The University of Florida was about 1% of the state's total EMERGY.

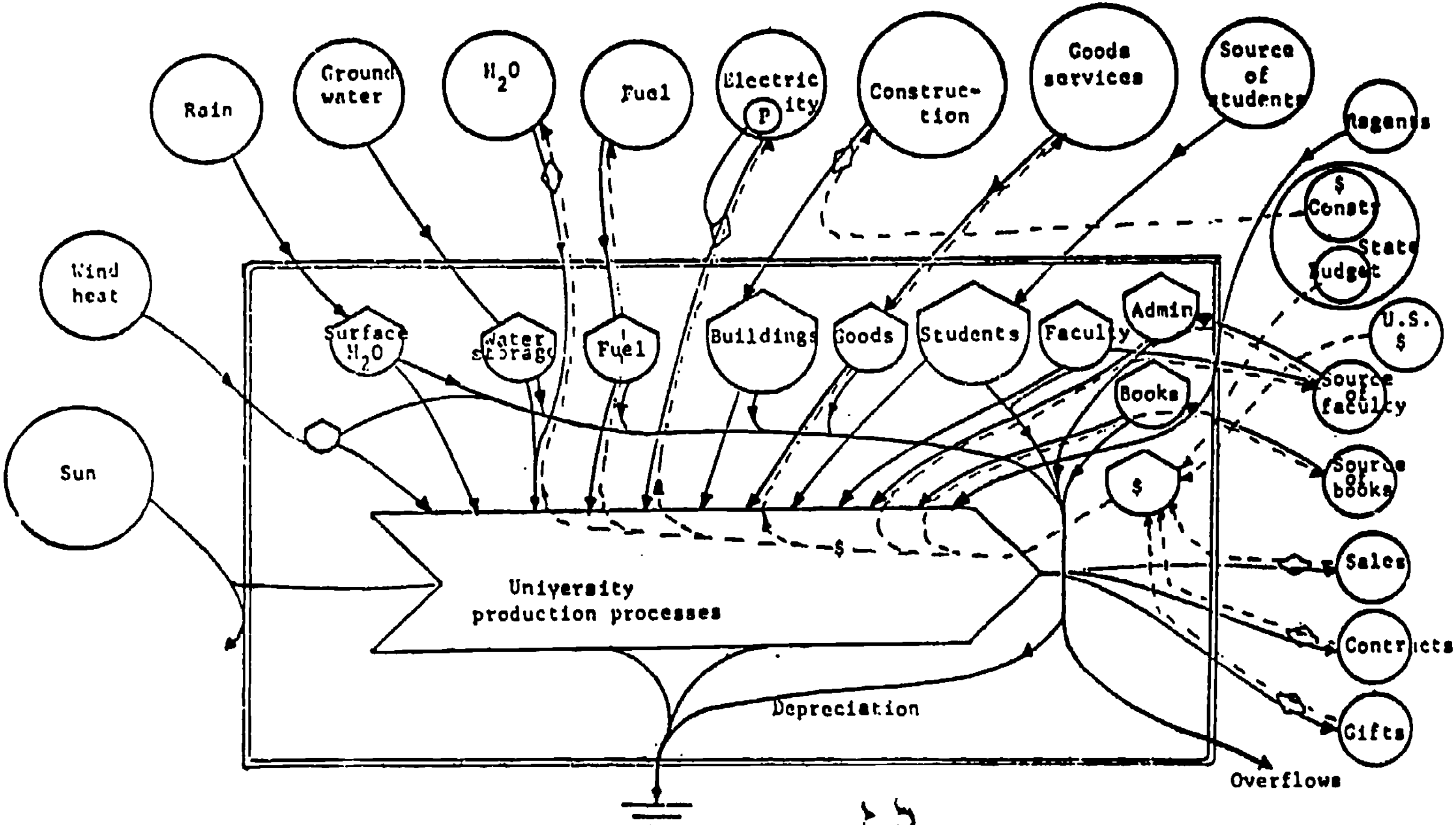

Figure 6. Production function of a university and its inputs. Money flows are dashed lines, counter currents against the inputs of items purchased.

Limiting Factors in University Production

Figure 6 shows the inputs to the university production functions. This is a summary of the several production functions in Figure 5. Table 1 shows large differences in the EMERGY inputs of these flows. Application of limiting factor theory to university production suggests that university contributions to society are greatest when available resources are applied to prevent any necessary input from being more limiting than any other. For example, development of southern state universities early in the century may have been limited by the poor backgrounds of their main student body. Some universities in undeveloped areas have a shortage of books even now.

The environmental setting is one of the EMERGY inputs, and its management for long term stability and low cost contributes to the university success. Although the environment is not large compared to the whole university function, it may be important to that part of human living functions that is low in the hierarchy, providing necessary living tranquility so that more attention can focus on the high levels of intellect. More plant diversity and native species make a campus more self-maintaining, maintains better water regime, reduces air conditioning costs, contributes aesthetic calm to stressed students.

Priorities for Internal Allocation of Funds

At the time of the energy crisis in 1974, President Robert Q. Marston of the University of Florida suggested we do an energy analysis of the University so as to help decide among priorities related to energy. Should available money go to improve efficiencies of university utility plants or should those funds go to other university needs? Since EMERGY received for dollars spent was similar to that for intellectual inputs, expenditures on utilities which could yield higher than 3.5 net EMERGY yield would be justified. Many energy conservation measures may have such savings.

State Priorities and High Technology

Allocation of funds within a state should be for that function that contributes most to maximizing the EMERGY use of the state. Calculating the EMERGY return on the dollar spent may be a way to compare higher education needs with others in the state. Also a state may compete best that develops higher solar transformities in its graduates because of their ability to tap outside funds and sources, adapt to change, and stay ahead with new technology.

A current belief is that societies that can build and maintain

concentrations of knowledge become the hierarchical center of culture and technology, other areas becoming coupled as a part of the support. As Figures 1 and 4 show, their support requires commensurate feedback so that the whole web is mutually reinforcing, causing the whole web to prevail against alternative outside or alternative designs that might take over. The university analysis suggests that information-rich activity has much more effect on the economy than indicated by the costs, supporting the need for maintaining educational levels.

However, there are now many hierarchical centers of knowledge and trade, and those which feed back more of their high quality outputs into basic production either at home or abroad may be the ones which become the centers in the next era. The United States, with high levels of consumer frenzy that do not feed back (luxury consumerism), has been losing its earlier central role in world hierarchies.

Information in International Exchange

EMERGY studies given elsewhere show the way the developed industrialized nations in their international trade with less developed countries received two to five times more EMERGY in imported raw products and fuels than is in the money they pay in return (Odum and Odun, 1983, 1987; Odum, 1984). The dangers to world welfare and peace of such inequities are well known from the experiences of the colonial era. However, the total exchange between nations may be more equal than the trade balance if enough information and knowledge goes back to the less developed countries. Universities thus play an important role in maximizing world functions by teaching foreign students, conducting exchange programs, and contributing work on the needs of those countries. Emergy evaluations of international information exchanges are yet to be made to find out if more information needs to feed back to supporting countries in order to make the system reinforcing and thus continuing. For an era of declining resources, staying at the information center may depend even more on higher efficiency in education and knowledge maintenance.

Suggestions for Universities on the Way Down

As resources readily available to society are declining, western civilization will be cresting in its growth and magnificence. Downtrends in structure and function may be starting already. Shared knowledge with a large territory has a slow depreciation rate. This means that knowledge is not rapidly lost when the resources for knowledge maintenance decrease. However, knowledge does require continual maintenance, and if society has fewer resources, there may be less for information. The university's role may be even more critical

in holding an advanced civilization together in times of declining resources when its support base may be decreasing.

Everyone knows how the products of universities have been used by society on the way up. However, not since the Middle Ages have universities been part of coming down. Patterns and policies must change to make life as vital in coming down as in times of growth. What are the future possibilities and responsibilities of the great university to guide civilization to a "prosperous way down?"

Some suggestions for transition are:

1. Increase efficiencies of teaching and retaining important knowledgeby using principles more.
2. Combine specialties by seeking the principles common to each.
3. Teach general systems concepts first and then the special cases.
4. Teach synthesis (putting parts together and dealing with largerscale mechanisms) because most of the problems and their solutionsare in the larger patterns of organization of Society and Nature.Analysis (looking at parts and smaller mechanisms) has been the main emphasis in science and humanities heretofore.
5. Discard the wasteful proposal-grant system where too much time is going into proposals. Provide support in production to what is being contributed.
6. Separate from the universities those functions not concerned with knowledge. Separate those students not interested in learning as a primary purpose.
7. Separate from the universities those functions concerned with short range problems. Inother words, activism on short range issues belongs elsewhere,although learning to pull truth out of controversy is a necessary part of education.
8. Package the information for which there is no longer a support base in long term storages in the same way that ecosystems keep rare species around as part of the gene pool.
9. A task force in social history may be needed to rediscover ways and means from the past that were effective in lower energy times and which may become useful again.
10. Maximum EMERGY principle can provide an objective basis for ethics while still keeping separation of religious truth (premises accepted without testing) and scientific truth (based on information derived from measuring the system and testing the consequences). The two kinds of truth are often reinforcing.
11. Continue to provide society with as many choices as possible, albeit less when there are fewer resources.
12. Retain the coupling with society rather than adopt the medievalmonastery

model for retaining knowledge.

Liberal Versus Specialized Education

An age-old dichotomy within the university has been liberal education versus specialized technical and professional education. Liberal education has provided people with interest and background for the large-scale, long-range, and public policy perspectives. Professional-technical curricula have provided people with intense levels of information, the basis of a high technology society. Both products are high level, but why has it been either one or the other? For the times of declining resources ahead, perhaps we need a general education that combines these better.

A Technical General Education Alternative

In a time of "coming down" when resources for education are less, a consolidation of knowledge may be needed with more emphasis on general principles, but without loss of the most important rigorous essentials. For example, for some years we have been guiding some students into a program we call "the Environmental Generalist." This is a scientitfic version of "liberal arts" education which retains a high technical level, but enough generality so graduates can adapt to the changing patterns of employment. Courses include the hard, detailed introductory units usually taken by professional specialists in various fields. The program is heavy in principles, content, and tools held together by general systems models, energy, and other unifying concepts and closely relevant to changing times through considerations of public policy questions concerned with adapting to a lower energy world.

An introductory course: The EMERGY analysis showed that educational levels before students reached the university were a main factor in the quality of the output. A text has been developed for advanced high school or introductory college-level students. It introduces general systems concepts to the study of environment, economics, and public policy. It uses microcomputer simulation to make systems overviews come alive. The simple BASIC programs are on disk, allowing students to consider alternatives. Courses using science and policy to introduce basic concepts of enviro . nt and society don't exist in many places yet, but a start has been made. With texts available, these courses that put everything in perspective should replace the miscellaneous bits of disciplinary science now taught in schools.

Summary

Putting universities and knowledge in perspective with hierarchical systems overviews suggests what is the successful role of universities in society, what maximizes knowledge and production, and what is essential for a prosperous way down. Task forces should already be working on campuses planning measures for retaining the essential of society's knowledge for an era of less support.

Works Cited

Boltzmann, L. "Der zweite Haupsatz der mechanishen warme Theorie." *Almanach der K. Acad. Wiss. Mechanishe, Wien, 36*, pp. 255-299, 1886, 1905.

Lotka, A.P. "A contribution to the energetics of evolution." *Proc. National Academy of Sciences*, U.S., 8:147-155, 1922.

Scienceman, D. "Energy and Emergy." pp. 257-276 in *Environmental Economics*, ed. by G. Pillet and T. Murota. Geneva: Roland Leimgruber, 1987.

Odum, H.T. *Environment, Power and Society*. New York: Wiley, 1971.

___. *Systems Ecology*. New York: Wiley, 1983.

___. "Embodied energy, foreign trade, and welfare of nations." pp. 185-200 in *Integrations of Economy and Ecology, an Outlook for the Eighties*, ed. by A.M. Jansson. Stockholm: Asko Laboratory, University of Stockholm, 1984a.

___. "Energy analysis of the environmental role in agriculture." pp. 24-51 in *Energy and agriculture*, ed. by G. Stanhill. Berlin: Springer, 1984b.

___. "Enmergy in Ecosystems." pp. 337-369 in *Ecosystem Theory and Application*, ed. by N. Polunin. New York: Wiley, 1985.

___. *Living with Complexity*. Royal Swedish Academy of Sciences, Crafoord Prize Lecture, Stockholm, Sweden, 1987.

___., T. Gayle, M.T. Brown, and J. Waldman. "Energy analysis of the University of Florida." Unpublished manuscript, Center for Wetlands, University of Florida, Gainesville, FL, 1978.

___. and E.C. Odum. *Energy Basis for Man and Nature*. New York: McGraw Hill, 2nd Ed, 1976, 1982.

___., and E.C. Odum. "Energy analysis overview of Nations." International Institute for Applied Systems Analysis, Working paper WP-83-82, Laxenburg, Austria, 1983.

___., E.C. Odum, M.T. Brown, D. Lahart, C. Bersok, J. Sendzimir, G.B. Scott, D. Scienceman, and N. Meith. "Environmental Systems and Public Policy." Ecological Economics Program Phelps Lab, University of Florida, Gainesville, FL, 1987.

The University and the Animal That Learns

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Humans differ from other animals in that they must learn virtually everything necessary to life. We evolved the capacity to learn from role models, these being parents, relatives, and other people of the tribe. Learning continued through the twenty long years of juvenility, when it was complete so that the new human was ready to take its place in the breeding population.

Learning would be of little use to the breeding adult, for whom the role fixed by natural selection was that of an optimal forager, a mass-producer of goods and services for the young. Learning would be no more welcome to the family-raising parent than experimental changes in procedure would be welcomed by a factory in full production. Natural selection, therefore, conditioned people to learn well when immature but to curtail the process sharply as adults. Or at least so I shall argue.

Those of us who seek to train people in universities take advantage of the ancient human trait that tells us to learn how to live while we are juvenile. This is why our students tend to be young. If we dare to extend our university power by also seeking to train the adults according to a policy of "life-long learning", we must heed, or circumvent, the ancient constraints on adult learning that are built into our genetic blue-prints.

The Model Offered Is Not Sociobiology

The argument to be offered in this essay is rooted in biology, although not in the behavioral disciplines of ethology or sociobiology. These subjects seek to understand human behavior by comparing it with the behaviors of other animals or by defining it as behavior directly induced by genetically

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controlled traits, so that we act as we do because we cannot help ourselves. Ethologists look upon humans as naked apes. Sociobiologists have been driven by their critics into speculating whether behaviors that drive human societies or mold the human condition might not sometimes derive from genetic mechanisms preserved by group selection. Whether the conclusions of these studies are fascinating or revolting depends upon your political preference.

But I take as a working principle that important human behavior is all learned behavior. We do indeed show our animal natures often enough. We get angry, we are afraid of heights, we like kissing, we play peek-a-boo with small children; when afflicted with intolerable stress, we hug one another. Yet these doings of ours, precious inheritance though they might be, are of relatively trivial importance to understanding the human condition.

The behavior that runs human social systems, from nation states to universities to village soviets, is all learned behavior. It is acquired by training. The truth of this statement should be self-evident; if it is not, a quick review of behavior in warfare (and of what it takes to make an aggressive soldier), will reveal the truth of the matter. Some behaviorists have argued that national aggression can be understood by likening it to aggressive behavior in animals, saying that attacking human soldiers and their leaders act in genetically determined rage.[1] But all good soldiers know this to be nonsense. The staff colleges of the world teach young officers that their first task is to help their soldiers keep cool, and to let them subdue dangerous emotions like anger or fear so that they can fight rationally. The Romans, who conquered a world with a trained army, called this process *disciplina*. Through discipline we overcome rage and other inherent agonistic behavior. Understanding human aggression, therefore, requires an understanding of how, in fact, we do not make war in ways prompted by the animal in our genes.

The essential property of humans is that we can set aside simple genetic instructions about how to behave and replace such instinctive behavior with behavior for which we have been trained. This training might have been done by others, or we might be self-trained. Either way the really interesting things we do cannot be understood by ethological or sociobiological analysis, however entertaining or revealing of personal foibles such an analysis might be.

Human ability to set aside genetic instructions in favor of learned behavior can be called **Conscious Prevention of Stimulated Behavior**. This phrase yields the unmemorable acronym CPSB, so I have thought of calling the principle "Genetic Override", which yields the acronym GO. But the Roman *disciplina* is doubtless good enough, and it is a term that has long been accepted into academic usage. *Homo sapiens* is the animal that can be disciplined. As I propose to show, this disciplining is easier when the animal

is young. Universities take advantage of the fact that humans can throw out their genetically constrained programs of behavior in favor of other attitudes and skills that are taught or learned through vicarious experience.

Selection For Learning

The first of our kind evolved under rules for living set entirely by natural selection. For contemporary humans this is no longer true because the state, or neighbors, or simple tradition, or medicine, will provide when they are faced with adversity. These civilized aids to personal survival did not exist in the early days, and the first humans emerged because natural selection let each individual (or perhaps collection of relatives) succeed at the game of reproduction and survival on its own personal merits. It follows that our ability consciously to override genetically determined behavior gave selective advantage to each individual that possessed it in those early human populations. Furthermore, the whole intellectual apparatus necessary to the trait of learning how to live must have increased relative fitness, as the biologists say. In other words, the clever ones in the prehuman population left more surviving offspring than the stupid. But that cleverness should lead to more surviving offspring is by no means self-evident.

It is a basic principle of evolutionary ecology that the way of life be constant down long runs of generations. The way of life of a species is fixed, and species are recognizably distinct because their ways of life are distinct. But an animal that arrives at a way of life by trial and error, or imitative learning, must be in danger of seeking to live in ways unlike those of its parents, violating the rule of keeping behavior constant from generation to generation. The peril inherent in intellectual power is that individuals will choose novel behavior when novelty is more likely disastrous than not. That cleverness is indeed perilous may be gauged by the fact that it has been permitted to emerge by natural selection only once in three thousand million years of evolution, although the necessary apparatus (a large brain) seems to be a simple technical step for evolution. Evidently selection against intelligence usually prevents its development.

The role of selection in enforcing uniformity of behavior from one generation to the next is revealed by the extreme constancy of species traits that give animals the appearance of breeding true. In reality, animals do not breed true at all; through the sexual recombination of genes, they produce a vast array of deviants with every reproductive act. Selection for a small subset of traits from amongst this array is what preserves species characteristics. Only those cast close to the mold of the parents survive to reproduce; all those of markedly deviant form or behavior are ruthlessly suppressed by natural selection. This rule must have applied to the evolution of the first humans no less than to all other species.

Deviant behavior most inimical to breeding success probably is behavior that leads to the excessive propensity to compete because the individual that must compete with other animals as well as with individuals of its own kind should always be at a disadvantage. Avoidance of excessive competition is the basis of the character displacement model of speciation, itself a development of the theory of competition and the principle of competitive exclusion (the Lotka - Volterra - Gause logistic model).[2] Fatal competition between species is usually avoided because specific ways of life are distinct, with the individuals of each species acting to conform to the niche of the species. Lifelong learning, as a way of fitting individuals to a particular niche, entails the special danger that individuals would tend to behave in ways causing them to stray from the parental niche, to suffer excess competition in consequence, and to pay the price of hereditary oblivion.

By "niche" is meant all that an individual of a species does to win resources and to turn those resources into offspring. Consider a wolf spider hunting across the forest floor. This spider does not build webs; it is a true hunter, running down the small prey on which it feeds. Hence its name. The niche of wolf-spidering includes extreme skill at pouncing on the small and the weak. But there is more to wolf spidering than just hunting; at the very least, one of the animal's eight eyes must ever be on the watch for the ferocious terror from above; the chicadee or the robin; those brutal engines of destruction so terrifyingly powerful to a wolf spider. So the wolf spider niche includes behaviors to avoid hunters as well as those that make it so superb a hunter itself. A wolf spider must also be programmed to act in the right way when it rains or when winter comes. If a male spider feels, as it were, the sap rising in its eight legs in the spring, it must be able to find a female spider; and act in such a way that she realizes he is not just something to eat: at least not yet. There is a ceremony to be performed before she eats him, adding the calories of his body to their joint stock for the making of babies. And so on.

The niche of wolf-spidering is no job for amateurs; only a superbly equipped professional can succeed at it. This is why wolf-spiders and all other living things seem to breed so true. Natural selection removes all but the most superbly successful and competent; deviants are eliminiated because they are denied significant opportunity for success in breeding. But perhaps the most dangerous form of deviation is that which leads to excessive competition with other species.

When beautifully fitted to its own niche, an individual must face strenuous competition with individuals of its own kind because these conspecifics are all alike and all use the same resources. Success in this intraspecific competition requires the most perfect attunement to niche. An individual who behaves differently from the rest should not usually escape intraspecific competition, but merely be less good at it than the others who conform more closely to the

pattern found to be successful by many generations of trial and error. But the deviant individual is more likely than the rest to encounter additional competition from different local species as their special resources come within its ambitions. Mavericks, therefore, are likely to encounter two doses of strong competition; intraspecific with their own kind and interspecific with other kinds; a double jeopardy that seriously reduces their chances of leaving many surviving offspring.

Formal theory predicts that species can coexist indefinitely only if they are so distinct and have such specialized tastes that competition between them is reduced to a minimum. Between two species populations there is, as it were, a killing ground of behavior. Deviant individuals whose constitution predisposes them to be different must inhabit this killing ground, and they will have little chance of leaving surviving offspring. Precisely this fact is emphasized by the character displacement model that explains the separation of species; the most distant characters in a blending population will suffer least competition and leave those offspring whose distinctive properties define the species of the future.[3]

This excursion into ecological niche theory is necessary to the argument because it shows the importance of continuity of behavior between generations. A niche must be fixed from daughter to daughter to daughter, enforcing a rigid "mother knows best" rule on all succeeding generations. For every species except our own, the essential properties of niche are fixed by genetic blueprint. Wolf spiders do what they do because their genes tell them to do it, and so it is with almost every other living thing. Animals can of course learn some behaviors, but these tend to be specialized functions that fit them even more closely to the prevailing local niche. The learning of bird songs, for instance, allows acquisition of particular local dialects so refined as to defy the possibilities of constructing a sufficiently detailed genetic code within the number of generations for which a local dialect would be useful in a changing world. Apes and birds of the rain forest learn when and where the forest trees bear fruit; without such local knowledge their niches of rain forest foragers would hardly be possible. But these examples of learned behavior are just a fitting of niche to precise local circumstance. For all animals except *Homo*, the basic patterns of behavior are fixed by the genetic mechanism. By this means the niche is fixed. But we humans learn everything that matters. We learn the niche.

We must learn what to eat, how to find it, what to avoid, how to escape, what is shelter and what is not. This is unique. But worse still, we learn the most vital forms of social behavior, putting aside the instructions of our genes, we act in different ways according to our training or choosing. Ethnologists of the "naked ape school" tacitly deny us this uniqueness, contending that we are creatures fitted to our niches by genes, like all other animals. For the purpose of this essay, I hold it to be self-evident that they

are wrong. The power of advanced learning that we call "intelligence" is certainly genetically fashioned, but it just as surely does not fit us to a fixed niche. It seems instead to violate the fixed niche rule, making us potentially quite plastic in tastes and wants, as our history has indeed shown us to be.

Thus, an ecological argument ends in paradox; the niche must be fixed, yet natural selection has given selective advantage to animals with so seemingly plastic a niche-fitting system as learning. This paradox can be resolved only if the niche acquired by learning can be shown to be inherently constrained. For the first humans, the learned niche must have been fixed into the shape of the mother's niche, despite the fact that it had been learned.

Basic human life-history traits ensure that this requirement can be met. First is the juvenile period, prolonged for roughly twenty years. During this time the infant is dependent on the services of those around it, most notably its mother. These are the years when the individual human learns how to live, acquiring the profession in life that ecologists call the niche. It learns its niche from the role model provided by its mother. Constraint of learning by the presence of a role model is not, of course, confined to humans. It is prevalent as well in other vertebrates that learn some parameters of niche. Birds that learn particular song dialects do so by copying the singers they hear in early life. Gibbons who must master the spatial and temporal placing of resources in a rain forest, have juvenile periods of helpless dependency on parents quite reminiscent of our own, some seven years. The gibbon life-history offers a clear hint of what occurs in an early stage in the progression of learning; all that is learned is a pattern of resources and most essential niche parameters are still fixed by genetic instruction. However, we have the propensity to be trained so that our behavior too is learned and our genetic instructions overridden; such an adaptive technique requires more that just time to learn from a role model. It requires a mechanism to assure that what is once learned is not unlearned.

The evolving human could not escape from the fundamental requirement that the adult niche must be fixed into the mold of the parents. It follows that the niche acquired by learning should result in the parental niche and nothing but the parental niche, and that no different behavior should be tried once the adult animal has left the parental role model to join the breeding population. For a learned niche to give selective advantage, therefore, the early populations of *Homo* must have been equipped with traits that ended the learning process once the individual was fully adult. In effect, the genetic instructions that control advanced learning must contain something like the following message, "Learn rapidly from role models when young, but cease to learn at maturity."

The plastic young and conservative adults predicted by this model are familiar enough to educators. They are also known to those seeking religious or secular power. The old Jesuit demand, "give me the child until it is seven"

illustrates the point, for the assumption is that, once the child has been given a particular religious orientation, it will never change. Another example is the use of child indoctrination by tyrants as with the Hitler Youth or the Young Communist Leagues. We can fix the social attitudes of the very young so that they tend to keep these attitudes for the rest of their lives.

Equally good are many data on human reluctance to learn important things like social behavior and food preferences as adults. A telling illustration is the well-known fact that military commanders in foreign campaigns must provide their soldiers with familiar food. Soldiers sometimes go hungry rather than eat strange food. In Viet Nam, critics have said that our soldiers needed machines dispensing iced coke, a decided handicap to soldiering, if true.

That the young learn and the old do not is an observation so familiar as to be trite. Yet its triteness does not lessen its importance. If the evolutionary arguments presented here are valid, this trite observation is actually of a genetically determined human condition. We have genetic instructions that impede learning. The conduct of universities must be influenced by these facts.

Testing The Model

The model presented above describes the constraints required if learning a niche is to be permitted by natural selection. The model emphasizes the hazards of learning, particularly the dangers inherent in learning to be different. Obviously there must have been strong, compensating selective advantage that more than offset these hazards, or intelligence could not have evolved at all; however, leaving these necessary benefits aside for the moment, definite hazards are predicted by the model, and these hazards are mitigated by built-in constraints on learning. The way of life of a successful role model is learned when young, but adult learning is impeded. Thus, the learning that makes universities possible is girt about with natural constraints, the strongest of which is that powers of learning decline with the onset of adulthood.

Because the niche is learned, the earliest humans acquired the hitherto unprecedented ability to change niche without speciating. Human populations could move into fresh habitats, or change basic resources, without any change in structure or genes. The changed behaviors always should be slow because the young copy the old way from parents, but slight changes from mother to daughter would be possible as the habitat or resources changed during the years of childhood. Such changes would actually increase fitness by defining the niche of the next generation to suit changed circumstance. Down runs of generations, these differences should compound so that the lives of distant descendants would differ markedly

from those of their ancestors in ways quite impossible for all other animals. Indeed, that future lives should so differ from ancestral lives, in humans but in no other animals, is a prediction of the model.

The test of this prediction is that early populations of hunting or gathering people spread over the whole earth, from Arctic to equator, in all imaginable habitats except the most savage of pure ice or pure desert. We did this before the advent of civilization, husbandry, or habitat control. No other animal has ever come close to this achievement. Descendants of all other animals enter new niches only by speciating, which is to say as a result of selection promoting subsets of genetic recombinations until a new program is found through the long and wasteful process of selective death. Our ancestors merely learned, in the span of a few generations, the subtle variations on niche needed in new habitats, then schooled their children in the new ways.

That the model is robust is suggested by the fact that it provides a satisfactory explanation of the phenomenon of race. The model does this because criteria to be used when choosing a mate are expected to be learned. If this was so for early human populations, then traditions in mate choice would be established in migrating populations as they spread to fresh habitats. There would be fashions in skin color, shape of lip, or texture of hair; just as there are modern fashions in skirt length for females or hair length for males, fashions still so important to social lives that obedience to them can influence an individual's chance of securing a mate even now. The purely superficial differences between human races, therefore, probably came about through fashions in mate selection in small founder populations, although it is possible that fashion sometimes reflected actual advantage, as when protection from sunlight is provided by adequate pigment in the skin.

A more general test of the model is suggested by its prediction of the adult conservatism that lets people cling to niches learned when young. People should find it difficult to live in ways markedly different from their parents, or at least in ways different from those to which they were raised. The prediction is upheld by the stubborn persistence of caste systems. A caste defines an ecological niche to the extent that members of a cast require a specific set of resources, both material and social, to live in the style for which their training fitted them. Children are trained to be part of a caste, either by parents, or by such social institutions as church schools that are employed as surrogate parents by members of a caste. A generation can live only in the way for which it was trained, and it passes this way on to yet another generation. And so the caste system persists, defying attempts at its destruction by legal, political, or economic means.

Another general test of the predicted conservatism is the persistence of cultural differences between nations. The ways people of a region think or behave apparently can last for centuries, certainly outliving political regimes.

Even the most autocratic of regimes can seldom change national character, whether for better or for worse. Only when the linkage between generations is broken are whole populations thrust from one culture to another, as perhaps happened when American schools took over education from immigrant parents to fashion a new national identity.

The model also appears to predict the phenomenon of religion. Religious belief puts some subjects as outside the boundaries of what can be learned, which could have been a valuable property for the first humans. Juveniles of evolving humans learned how to live mostly from parents but also, inevitably for a thinking animal, by questioning the environment itself. They would then encounter unanswerable questions like "what are the stars" and "where do I come from". Neither mother nor reason could answer these with the data set available, and yet the question could not be left unanswered because learning time would be wasted in their eternal repetition. The natural selection model therefore predicts that a mechanism must be in place to stop unproductive questioning. When a question could not be answered after several tries, there should be a feed-back loop which says simply "because it is so and that is the end of the matter." It is quite impossible to imagine a learning animal not equipped with such an intellectual shunting device to prevent mental self-destruction when confronted by the imponderable. For this reason, the model predicts a propensity fo: religious belief of the kind that asserts " 'I am' made it so" as a necessary, genetically endowed property of humans.

In summary, the model's general requirement -- that we are animals that learn well when young but which reject the unfamiliar as adult -- seems to fit many of our known properties. To the extent that it does so, the model survives testing against human experience. The conclusions may be trite, since so familiar, but they are not trivial. In particular, this formal statement of the familiar suggests that attempts to alter the lives of people through university education must encounter resistance to change. This resistance is an essential and individual human characteristic, not just an artefact of recent social experience.

But even adults can override genetic instructions about how to behave. We can consciously prevent stimulated behavior, even when this behavior involves the adult's reluctance to learn the new. If many individuals among the professoriate retain their intellectual curiosity, it is because a willful act of self-training has given them the skill to override personal injunctions to retain habits or explanations that were accepted in the past. And people who are not professors can be retrained to new skills or professions in later life, although only when their motivation is particularly strong. Even the comforting intellectual shunt that subsumes all explanations under religious belief can be thrust aside, though sometimes this move is a very difficult one to make. The opportunities for the universities of the future are constrained

by all these possibilities: youthful openness to learning, adult conservatism, and the conscious override of this conservatism as a prerequisite for continual learning.

The model of learning outlined above says nothing of the selective advantage which learning how to live must have given the first humans; instead it has concentrated on the necessary constraints. Anthropologists usually argue that the advantages of intelligence are self-evident; making weapons, tapping fresh resources or more varied resources, controlling the environment, and the rest. I doubt that these advantages were significant among early populations because learning of the kind that tapped fresh resources would entail a departure from the ancestral niche with precisely the consequences of increased competition or inappropriate response that adult conservatism works to suppress. Instead it is possible to construct a model in which the selective advantage of intelligence accrues to reproductive females that are able to train offspring of different genetic make-up to identical optimum behavior. This should increase infant survival, and hence the effective fecundity of the mother. Intelligence, and the associated ability to pass information from generation to generation through language, should also help the breeding effort through intelligent regulation of family size.[4]

Advanced learning might have given our remote ancestors several possible selective advantages, and it surely gave them at least some. But my argument here is that, whatever advantages were bestowed, the habit of learning how to live, with its unprecedented property of being able to override genetic instructions required also that learning be constrained. A long juvenile period was required, typically consisting of an apprenticeship to parents. Such a model can be used to support the argument that the family is a natural human grouping for the encouragement of learning, a grouping in which natural selection allowed intelligence to be favored. During the long juvenile period, human young are receptive to training, to learning by experience, to acquiring attitudes necessary for social life. Once humans become mature adults ready to take their places in the breeding population, they are expected to be more or less resistent to new learning.

The University and The Animal That Learns

A university takes its student clients in the closing stages of the natural learning process. The professoriate has always been aware, at least dimly, of this pervasive reality, knowing that what it dare teach students is in some large measure dependent on what has been taught them before. Students must be literate and numerate before traditional university teaching can even begin. But what is more fundamental to the aspirations of a university is that the social attitudes and beliefs of the university's clients are already firmly in place when they arrive on campus. Individuals have been fitted to the most

important parameters of niche before they reach the university. These are the parameters that tell them how to behave in the adult social setting that they are about to enter.

The university, therefore, admits students who bring to it social philosophies learned earlier from other mentors. The penchant for conservatism of pending adulthood is already present in these students, and they will not easily change their ways. They are more likely to make over the university society in their own image than to be directed in the ways considered appropriate by their professors. This is why the social feel and the political leaning of a great university can change radically with the coming of a fresh cohort of students.

A cynic's view of a university thus might be that its principal social function is to collect together an elite of young people, chosen and educated by other instruments of society, so that they can amplify their received opinions by shouting together. School, parents, peers, church, *Hitler Jugend*, or the media will have trained the cohort in a prevailing idea which they then bring to the university in the expectation of expounding it. The politicized universities of many Latin American countries are extreme examples of this process. Those of us in America who have witnessed the rapid change from left-wing activism to materialistic preoccupations with wealth and status have watched a milder form of the process. Neither the professoriate nor its teachings had any appreciable influence on this change.

That the university might have little importance as a molder of ideas is not a comforting idea to a liberal-minded professor. Yet this is precisely what should be expected if humans are programmed to learn social concepts while young, and if social learning is terminated at maturity. In a recent course introducing ecology at the beginning level, one of my students complained, in a written course evaluation, "I had difficulty with this course . . . . It was strongly based on ideas of natural selection that I don't hold with." We cannot even teach science at a university level to people who have been trained when younger to accept a philosophy that denies science.

Apart from being a mere amplifier of social trends learned elsewhere, the university can change social values only to the extent that its clients are not fully mature, not already fixed into life's niche. Some younger students are still open to training in even their more intimate beliefs, and the hope of garnering these students brings the cults, both secular and priestly, to the university campus. The professoriate can win some of these students, but it is more likely that they will be captured by general views of the cohort to which they belong. Seen from this perspective, the university becomes the final coaching house in which the learning animals of a generation are fixed in that generation's beliefs.

Nevertheless, the university can change human beliefs because of the vital human ability consciously to override previous instructions, whether genetic

or learned. Professors change their own beliefs when they destroy their own conclusions and replace them with the new ones. Graduate and professional schools inevitably do the same thing for students because they train people on into the early years of maturity when they should normally have been set in their ways. In these years, study itself requires the conscious exercise of continual learning, and the rigors of graduate study assume that concepts already established must continually be reexamined.

There is little doubt that the products of graduate and professional schools have significant influence in setting the social attitudes of the next generation. Some might become school teachers, although most school teachers today are closer in training and outlook to the holders of bachelor's degrees than they are to the true products of graduate schools. These school teachers will take to the next generation the views of their own student cohort, these being attitudes and behaviors they brought to the university and took away unchanged. But advanced training in graduate schools should produce some opinion molders whose views have been refashioned in novel ways at the university.

This analysis leads to a surprising paradox. Despite the fact that adults are expected to learn new ideas less easily than are the young, the most powerful way in which a university can mold the polity in which it exists is through adult education. When the young come to a university, they are already old enough to bring with them the baggage of preconceived ideas. Unless they are strongly motivated toward scholarship, the university function is largely to let them rationalize these ideas in concert. But graduate study and study later in life are predicated on having students themselves consciously decide to prevent their previously stimulated behavior; or at least to abandon old knowledge for new. In this development might be found increased power for universities to shape their societies.

The Future Power of Universities

Training people is potentially a source of power, possibly the most important source of power there is. This power resides partly in the very conservatism which reduces an adult's propensity to learn new ideas. Train young people to join your camp and they will be yours for the rest of their lives!

The power resulting from training the young has long been known. Many a state religion has won power for its members because it trained people in its beliefs, and modern autocratic regimes have deliberately sought to emulate them with programs ranging from Red Guards to Hitler Youth. The ancient Roman Republic trained the male children of its dominant citizens in techniques of war on its *campus martius*. This practice produced armies technically so superior to any others of the period that the power of empire

resulted. All successful conquerors have emulated the Romans by striking with highly trained armies.[5]

Democratic governments do not believe in disciplining the populace as the autocrats do, indeed they are suspicious of all notions of discipline as being part way to coercion. And yet politicians in democracies act as if an educated electorate is a necessary prerequisite to wise government, and democracies last only when people are educated. This is another way of saying that the power of democratic governments to renew themselves depends on people being trained to the ways of democratic government. So education can be a source of personal, political, or national power, whatever the system of government. It is, therefore, a process which all the estates of any realm will try to influence.

Educational power accruing to universities in the future should increase because university teaching has become necessary to modern economies. Degrees are essential for much of the workforce as universities provide technical training that the state cannot do without. Undergraduates must be schooled in engineering, business management, or biotechnology, even if the state is persuaded that it can manage without classics scholars. Even more importantly the professions must be staffed with the products of graduate or professional schools. Some of this instruction, like the training of graduate students, cannot be undertaken at all without forcing individuals to reexamine and to challenge accepted doctrines. As the proportion of the populace going to college or taking advanced degrees rises, so must relative university power increase. This rising power will bring increasing political pressure on universities.

But university power is constrained by the ages at which it receives people. By their seventeenth year students have already been inculcated with basic religious, social, and political beliefs; the juvenile period of receptiveness to all training is nearly over, and already they are beginning to be fixed into their adult niches. The universities, therefore, cannot be as dangerous, or hopeful, to rival power interests as are the schools, in which a little meddling can bring the rewards of people recruited to your camp or denied to the camp of your opponent. This explains why universities typically experience less interference or regulation from the state than do schools.

Restraint by politicians in the regulation of universities could be less evident in future, however, as universities devote more effort to retraining people in programs of adult education. This retraining, whether in professional schools or in programs of life-long learning, inescapably requires that individuals consciously set aside what they have previously learned. The immediate goals may be technical or economic proficiency, but the very process involves rethinking what has already been settled. When universities take adults in their middle prime in order to retool them to different lives, they potentially could alter the social and political leanings of people.

Universities will become more interesting to politicians as a result.

The stubborn resistance of universities to the admission of women to the professoriate must be intimately related to the power the universities wield. Feminism is the most fundamental challenge to widely-held beliefs in recent centuries and to admit women into society's official instrument for challenging beliefs, the research university, is to endanger the believers themselves. Women as students could be absorbed, up to a point, because students have already been schooled into society's doctrines before reaching the university. But to let women into the ranks of those whose calling it is to question belief is not willingly done by males trained in a society whose ethic has long been male supremacy.

The predominance of research over undergraduate teaching in evaluating faculty or assessing greatness in universities stems from the difference in relative power accruing from the two activities. Undergraduate teaching bestows little power, no matter how large the classes are, for the teacher expounds before a cohort that has brought its beliefs to the university. President Derek Bok of Harvard tells a tale which is an unwitting reflection of this fact when he refers to one of his predecessors' answers to the question, "what makes Harvard so learned a place?" The reply was, "because all the brightest students bring their learning here and leave some of it behind." This reply actually encapsulates the essence of undergraduate life and demonstrates why politicians and the clergy concentrate their attempts at influence upon primary and secondary education.

In contrast, research and graduate training bring power both by promoting the new knowledge or professional expertise necessary to economic progress and by challenging accepted beliefs. A professor who can do either is valuable, and the university that can support many such professors is known as "one of our great research universities." Society recognizes that creating knowledge and challenging accepted ideas are important functions, and values them accordingly. Sometimes it fears them, and again acts accordingly. This might be a reason for separating research scholars from university teachers by keeping research in national institutes, as in the Soviet Union or in the Germany of the Kaisers. In this way the dangerous thinkers are kept as isolated from students as possible.

The universities of the future will continue to emphasize research over teaching. They will become relatively more powerful than they are now, particularly as they develop into instruments for adult retraining. But increased power will also make them more subject than before to constraints placed upon them by the political process.

Notes

[1] Lorenz, K. 1966. *On Aggression*, London: Methuen. Opposing views are reviewed in Montagu, M.F. Ashley, ed., 1973. *Man and Aggression*, Oxford: Oxford University Press.

[2] For a review of competition theory, and other ecological concepts introduced in this essay, see Hutchison, G.E., 1978. *An Introduction to Population Ecology*, New Haven: Yale University Press. A popular account is given in Colinvaux, P.A. 1978. *Why Big Fierce Animals are Rare*, Princeton: Princeton University Press.

[3] Brown, L.L. and Wilson, E.O., 1956. "Character Displacement," *Systematic Zoology* 5: 49-64. References in footnote 2 include discussions of character displacement.

[4] Theory of regulation of clutch-size will be found in Lack, D.L., 1968. *Ecological Adaptations for Breeding in Birds*, London: Methuen. The family (clutch) size model of selective advantage of intelligence is given in Colinvaux, P.A., 1982. "Towards a Theory of History: Fitness, Niche, and Clutch of *Homo sapiens*", *Journal of Ecology* 70: 393-412.

[5] Colinvaux, P.A., 1980. *The Fates of Nations: A Biologcial Theory of History*", New York: Simon and Schuster; and Colinvaux, 1975. "An Ecologist's View of History", *Yale Review* 64: 357-369.

The Wo/Man Scientist: Issues of Sex and Gender in the Pursuit of Science

Evelyn Fox Keller

Introduction

My purpose in this essay is to argue for a shift in the focus of our deliberations -- from the subject of "women and the pursuit of science" to that of men *and* women in the pursuit of science. That is to say, I wish to insert a third pole into our discussion. By its very insertion, this pole raises a question where before there was none -- a question about those very aspects of the relation between men and science that are otherwise assumed to be so normal and natural. Before we can adequately address the question of equity between men and women in the working world of scientific pursuits, we must first find a way of introducing parity into the questions we ask -- our starting assumptions -- about men's and women's relations to the pursuit of science. How might we attempt to do this?

On the surface, there appears to be a simple way of introducing parity into our conceptualization of the relations of men and women to science. It consists of denying that there are significant (i.e. relevant) differences between men and women, making of them (at least in relation to science) one genre, namely human. Indeed, this assumption is virtually requisite to Western liberal ideology,[1] even if it has not been honored in Western liberal practice. With such a move, our discussion again becomes bi-polar, but with a significant difference: the two terms are no longer "women and science," but "humans and science." Conceptual parity is effectively introduced by fiat: men's and women's relations to the pursuit of science ought to be equal because these relations are the same.

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Any differences that might in fact be observed are attributable not to the *nature* of men, women, or science, but merely to the persistence of residual prejudices (i.e., expectations born out of ignorance).

It is this apparently simple approach that has been usually adopted by recent generations of American women scientists in their efforts to attain equity in science. I will argue, however, that such a formulation is not only inadequate in practice, having failed to secure equity for women scientists, but also inadequate in principle. Above all, it does not take into account the extent to which beliefs (call them prejudices, if you will) are internalized by actual men and women, and even, though less obviously, by the practices of science. Accordingly, collapsing the two terms, men and women, into one (colloquially, "man") foregoes the possibility of perceiving the extent to which "universal man" has historically been modelled on a particular cultural experience of manhood; in turn, it also obscures the ways in which norms of masculinity have been covertly absorbed into science.

True parity in conceptualizing the relations between men and women and the pursuit of science requires a more complex taxonomy -- one that not only preserves all three terms (men, women, and science), but one that simultaneously acknowledges the socially constituted character of each term. This last point must be underscored, precisely because it is so frequently lost from view. It requires us to make two crucial distinctions: one between sex and gender and the other between nature and science. If sex is a biological category into which we are born as male or female infants, gender is a cultural category that shapes our maturation into adult men and women. In this sense, gender represents a cultural transformation of sex. In much the same way, science represents (or gives to us in representation) a cultural transformation of nature. Nature, in short, does not appear to us unmediated. Representations of nature take their shape from the instruments, theories, and values that particular scientists bring to the task of "revealing" nature. Just as the character (and values) of a culture as reflected in its socially agreed-upon definitions of masculinity and femininity (i.e., its gender ideals), so too, the particular instruments, theories, and values that scientists employ in their attempt to represent nature are reflected in the picture of nature that emerges from their desks and laboratories. In other words, while sex and nature might perhaps be said to be givens, gender and science can not. Gender is the culturally mediated guise in which sex appears to us, while science gives, in equally culturally mediated guise, our representations of nature. This intrusion of culture -- between sex and gender on the one hand, between nature and science on the other -- fatally undermines any confidence we might have had in the monolithic character of either of the categories, gender or science.

In an attempt to illustrate the political and conceptual inadequacy of the "liberal" approach to the question of women in science (i.e., the denial of substantive and pertinent difference between men and women), I will begin a brief and necessarily sketchy review of the problems encountered

during the history of its employment by American women scientists over the past century. I will then discuss the advantages of the more complex taxonomy I have suggested, particularly in relation to some of the current issues confounding the problem of equity for women scientists. First, however, it is necessary to indicate the historical context in which a "liberal" strategy seemed so great a step forward.[2]

Historical Background

During the late nineteenth century, the strategies invoked by women aspiring to admission to the world of science were often aimed more toward accommodation than toward equity. As such, they might be described as "pre-liberal" -- many women scientists resigned themselves to (or sometimes actively sought) a secondary demarcation within the realm of science, accepting a feminine subsphere within the larger male sphere, no doubt hoping that a kind of equality could be attained within that subsphere. Although this strategy may have created educational opportunities, its ultimate inadequacy as a professional strategy was soon recognized: it doomed those women who had managed to enter the world of science to women's work -- i.e., work that was poorly remunerated, low in status, and generally regarded as intellectually inferior (see, e.g., Rossiter, 1983).

As a consequence, separatist strategies gave way to strategies of integration. In making this important move, women scientists saw a natural ally in scientific claims to objectivity and neutrality. If the production of science is independent of its producers, there should be no place for gender (or, for that matter, for race, religion, or other social markers) in the discourse in which it is grounded. And if scientific minds are truly disembodied, it is irrelevant whether the body of a scientist is male or female. Accordingly, women with scientific minds should be able to claim access to science equal to that of men.

The question in many people's minds was of course whether women actually do have scientific minds -- a question invoking the spectre of difference in a frame that automatically undermined women scientists' claims to equity. For the last one hundred years, this question has defined the principle contest between feminists and non-feminists in the

struggle to define the relationship between women and science. By the early part of this century, scientific feminists -- both in the sense of feminists who were scientists and in the sense of feminists who grounded their political theory in scientific principles -- had come to see how readily claims of differences are translated into conditions of inequity. With this recognition came the conviction that it was necessary to stake their claims to equity on the repudiation of the myth of a feminine mind -- i.e., on the refutation of difference. In an effort to discredit traditional views of innate, biological differences between the sexes (particularly in the domain of cognitive

capacities) and to demonstrate the importance of environmental and institutional factors, they worked hard to gather psychological, sociological, and anthropological data on men and women. Their need to refute claims of natural difference seemed absolute -- on their success, they thought, would rest the entire future of women in science. So confident were they in the correctness of their views on the one hand, and in the objectivity of science on the other, that they felt it was sufficient to rely on agreed-upon standards of scientific rigor to demonstrate and expose the flawed reasoning pervading popular belief.

In retrospect, we can see that the confidence these women scientists had in the standards of scientific rigor was excessive. Feminist scientists were not the only ones interested in the science of sex differences, and in time, the subject was wrested out of their hands. Indeed, some of their data, collected to demonstrate the social obstacles facing women scientists, was later reinterpreted by other scientists to demonstrate not the need for, but the futility of, increased opportunity for women in science.[3]

In one of the saddest episodes of women's history in this country, the tide soon turned against these early feminists, eroding many of the gains they had made. By the 1950s, the proportion of women scientists had declined to roughly half of what it had been during the early part of the century. In 1956, almost a century after admitting Ellen Swallow Richards as its first female student, M.I.T. convened a special committee to consider whether or not to continue admitting women students; the recommendation of the committee was the termination of co-education at the school (see Keller, 1981).

During this dark period, all signs of the earlier feminists in science, proudly asserting themselves as women even while insisting on their intellectual equality, had vanished. In their place arose a generation of women who sought to sustain their struggle to be scientists by tacitly agreeing to expunge from their professional identity the fact that they were women. They too were committed to equity, but in ways that differed from those of their predecessors; they sought safety in the absence of any distinguishing characteristics, interests, or mental attributes that might mark them as women. Women scientists in the 1950's sought survival not only in the promised gender neutrality of science, but in the promise of their own gender neutrality as well. "Making it" meant making it as a scientist indistinguishable from other scientists. However, since other scientists were male, this meant eradicating any sign of difference between themselves and the men in their profession. If a difference was to be marked, it was more likely to be their difference from other women. It is perhaps not surprising, then, that, *qua women*, they effectively disappeared from American science. Their numerical representation was no longer so assiduously recorded by academic feminists, and in many cases, it was not recorded at all (Rossiter, personal communication; see also Keller, 1981). Often, by their own choice, their tell-tale first names were withheld from publications.

The overall impression is that these women no longer relied on science to

prove their intellectual equality as a class -- only to accept their own individual demonstrations of equality. They maintained absolute confidence in the fairness and objectivity of science to prove, and reward, their performance as individual scientists -- especially if they succeeded in eradicating any sign of their own gender, any sign of their membership in the class from which they seemed to have escaped. Unfortunately, hindsight permits us to see that this strategy failed to protect these women scientists from the effects of an increasingly exclusionary professional policy -- it only helped obscure the effects of that policy. Not only the numbers, but also the status of women scientists (as individuals and as a class) deteriorated steadily.

Even when the fortunes of women in science began to improve in the late 1960's and early 1970's -- partly in response to Sputnik and partly in response to the emerging women's movement -- the commitment among women scientists to the idea that gender is irrelevant to the practive of science, remained strong. A personal anecdote may be relevant here. In 1974, I decided to examine the subject of women in science in one of a series of scientific lectures I was invited to give at the University of Maryland. I recall, even now, the trepidations I felt. Merely to introduce the question of women in science within a professional setting seemed like a bold and even dangerous move.

Supported by national efforts to expand our scientific workforce, however, real improvements gradually began to be made. Women started to count themselves again, to recognize one another, and even to counsel one another. The dramatic improvement in the status of women at M.I.T. over the last twenty years provides clear testimony to the effectiveness of such collective efforts. But the reclamation of their group consciousness as women, at M.I.T. and elsewhere, simultaneously rekindled their other need to transform (if not to efface) male consciousness of them as women. It revived the paradox that Nancy Cott (1987) describes as having plagued the entire history of modern feminism -- a paradox that faced women scientists with particular urgency. Almost as a consequence of the reemergence of their identification as women, their commitment to intellectual sameness -- to the repudiation of difference -- returned with renewed force. Once again, they regarded their principal target as claims of innate sex differences in mental attributes, particularly those that were now issuing from within the scientific community itself.

These claims have been undergoing a particularly vigorous revival in recent years, keeping pace, as several authors have pointed out, with the successes of modern feminism. Accordingly, the scientific rebuttal of sex-difference claims has resurfaced as a principal concern of contemporary feminist scientists. Over the last decade, a number of critical reviews devoted to this end have been published, all of them aimed at undermining the scientific quality of such claims. Some of them have even suggested that the inquiry into a biological basis of behavioral differences between men and

women is itself an inherently sexist endeavor.

The necessity of these efforts is obvious, but so is their vulnerability and (perhaps inevitable) defensiveness. Each new claim of a hormonal or physiological correlate to suspected or known sex-linked behavioral attributes needs to be freshly examined, its fatal undermining flaw identified and exposed. Fueled at least in part by continuing reports of observed differences in behavior and performance between men and women scientists (or between male and female students), this effort is ongoing and, as the scientific quality of such research improves, increasingly demanding. Furthermore, the very terms of the debate about sex differences lends support to characteristic kinds of cultural myopia. But before we can correct -- or even become aware of -- such short-sightedness, we must introduce a third term into our deliberations, shifting the discussion from "women and science" to "men, women, and science" and bearing in mind, as we make this shift, that none of these categories is itself monolithic.

Typically, the debate about sex differences focuses on the nature or nurture of men as a norm. In such discourse, gender is not understood as a term that refers equally to both men and women; it tends to be read and heard primarily (if not exclusively) as a reference to women. Accordingly, the possibility remains unexamined that aspects of stereotypic male psychology or rather, normative conventions of male socialization, may unwittingly have been incorporated into the very measures and standards employed in assessing (or characterizing) the behavior and performance both of women and of men growing up under cultural norms different from those of white middle-class culture. I offer three examples to illustrate this point.

One particular claim of differences between male and female mental attributes has become a principal focus for feminist critics in science; it derives from differences observed in the performances of girls and boys on Standard Aptitude Tests (Benbow and Stanley, 1980). Although critics have pointed out that these test scores correlate poorly, if at all, with creative performance of actual mathematicians, the question of what these test scores *do* correlate with has not been pursued. To what extent are they merely correlates of what some boys in our culture are (directly or indirectly) encouraged to do? Or have learned as part of their masculine identity? In other words, to what extent do our routinely accepted criteria of scientific intelligence faithfully measure actual ability to perform intellectual tasks in the world at large, and to what extent are they inadvertent reflections of particular (gender-biased) cultural norms?

A second example involves a possible cause of continuing inequity that was considered at a conference on women in science convened by the Macy Foundation in 1981.[4] Concluding that most traditional forms of discrimination were no longer visibly operative, it was suggested in the course of discussion that one definitive and ongoing handicap *could* be identified: nen were not trained to be sufficiently competitive to survive and prosper he cutting edge of contemporary research. The recommendation that

follows from this observation seemed obvious: retrain women to be more competitive. The question that was *not* raised was whether the norms of competition currently accepted by scientists are accepted because they are norms of male socialization (and hence not visible as norms), or because they are necessary, or at least conducive, to good research. To phrase the matter bluntly, is it necessary or even good for physics that, as one eminent physicist has said, "only blunt, bright bastards make it is this business" (quoted in Traweek, 1984)?

A third example is more banal. It has to do with the common practice of measuring scientific productivity by counting the total number of papers of which one is an author. The number of papers on which the name of a principal investigator appears will, in general, depend directly on the size of the laboratory or group he or she heads. Suppose that (for whatever social or psychological reasons) most women scientists prefer to lead small groups. These scientists would obviously tend to have a lower "productivity." If such measures of productivity are used to infer quality of science, it would follow that large labs (or groups) produce better science than small ones -- a proposition that no one would accept if it were stated so directly.

Caught on the horns of an impossible dilemma, women scientists of the twentieth century have tended to seek equity through the refutation of difference claims. Historical experience has taught us the vulnerability and ultimate inadequacy of that strategy, but it has also taught us that assertions of difference tend in practice to be self-defeating: acknowledgement of gender-based difference has almost invariably been employed as a justification for exclusion. To the extent that measures of scientific performance admit of only a single scale, to be seen as different is to be judged lesser. In the face of such a universal standard, the hope of equity, indeed, the very concept of equity, appears to depend on the disavowal of difference.[5]

In hindsight, however, one can see the pitfalls of this strategy: if a universal standard equates difference with inequality, the same standard would translate equality into sameness, guaranteeing the exclusion of any experience, perception, or value that *is* other. As a consequence, "others" are eligible for inclusion only to the extent that they can excise those differences and eradicate all traces of that excision. Yet such operations not only fail to provide effective protection against whatever *de facto* discrimination continues to prevail; they often prove only partially successful, leaving in their wake residual scars that prevent those who do survive from becoming fully effective "competitors." Successful assimilation has thus tended to require not *equal* ability, but *extra* ability -- the extra ability to compensate for the hidden costs incurred by the denial or suppression of a past history as "other."

As long as we accept a conception of science as a monolithic venture -- [...]ned by a single goal and a single standard of success -- *neither* the

assertion *nor* the denial of difference can procure equity for women in science (or, for that matter, for any other "others"). Indeed, the very assumption of a universal standard mitigates against equality for the carriers of any residual difference, whatever its source. This is *the* dilemma that has entrapped women scientists throughout their entire history.

Fortunately, our understanding of the nature of scientific knowledge has moved a long way from such a univocal conception during the last few decades. Recent developments in the history and philosophy of science have led to a reevaluation in which it is acknowledged that the goals, methods, theories, and even the actual data of the natural sciences are *not* written *in* nature; *all* are subject to the inevitable play of social forces. Empirical and logical exigencies may train the representations of nature that emerge from the desks and laboratories of scientists, but they do not determine it. Social, psychological, and political norms are inescapable, and they too influence the questions we ask, the methods we choose, the explanations we find satisfying, and even the data we deem worthy of recording.

Such a shift in our conception of science provides a way out of the dilemma faced by earlier feminists in science. To the extent that we acknowledge a multiplicity of goals and standards in science, it becomes possible (at least in principle) to argue for the inclusion of difference -- in experience, perceptions, and values -- as intrinsically valuable to the production of science; hence, it becomes possible to envision equality without sameness. But a trap resides in this proposition as well -- a trap that derives from the familiar and widespread temptation to map difference on to sex. Behind this temptation is the assumption that difference means duality and implies that women as a class will do a different (or "feminine") kind of science. However, such a proposition ignores the lessons we have learned from the history of women in science -- lessons that show, for example, how readily exclusion can follow from the equation of difference with duality. It also fails to do justice to the enormous variability evident among actual women.

If recent work in the history and philosophy of science has sensitized us to the influence of social forces in the development of science, recent work in feminist scholarship has sensitized us to the role of social forces in shaping the development of men and women -- i.e., in defining gender norms. It has also sensitized us to the historical importance of the complex psycho-social dynamics that have woven contemporary norms of gender and of science into an inextricable web. The proposition that, under conditions of equality, women would do a different kind of science, a more "feminine science," ignores the extent to which both women and "femininity" are socially constructed categories. More importantly, it ignores the extent to which our contemporary conceptions of femininity and science have been historically constructed in opposition to each other. If science has come to mean [objectivity], reason, dispassion, and power, femininity has come to mean [everything] that science is not: subjectivity, feeling, passion, and impotence.

Ignoring the force of cultural labels in the construction of these categories invites their acceptance as "natural"; for this reason, it militates against the possibility of reconstructing or reevaluating them. Furthermore, if we do not attend to the force of cultural dynamics in the construction of the norms that have defined the meaning of masculine, feminine, and scientific, we remain oblivious to the uses to which these constructions have been put.

I have argued elsewhere (Keller, 1985) that the exclusion of the feminine from science has been historically constitutive of a particular definition of science: a definition of science as incontrovertibly objective, universal, impersonal -- and also masculine. Such definition both helps ensure the invulnerability of science in the face of social criticism, *and* serves to demarcate male from female. It is a definition that sustains and is sustained by a particular (culturally specific) division of emotional and intellectual labor -- a division along the lines of sex. In the past as in the present, this sexual division of labor has provided critical support for just those claims that science makes to a univocal and hence absolute epistemic authority. That same authority has, in turn, served to denigrate the entire excluded realm of the feminine. Because science itself plays a role in these complex cultural and historical dynamics, any discussion of men and women in science must take into account the presence of gender-laden cultural biases in the very definition of science. Failure to do so is to overlook an important channel through which particular cultural values are imported into the norms invoked for distinguishing "good" science from "bad" science. It is in just this process that *de facto* discrimination is often practiced against individuals or groups who happen to bring with them any of those values that, for reasons having nothing to do with scientific productivity, have been pre-judged as undesirable.[6]

Finally, it is in the name of scientific productivity as well as equity that we must recognize both the value of difference *and* its extent. The enormous variability (both cultural and individual) that exists among actual men and women goes well beyond biological variability, either between or within the categories of male and female (i.e., sex). First, there is the cultural variability between different concepts of "masculinity" and "femininity" (i.e., gender). But, in addition, there may be even greater variability in the degree to which individual men and women conform to or diverge from the gender norms (or stereotypes) of their particular cultural frames. To forget these last sources of difference is both to ignore the diversity of human culture and to do an injustice to those women scientists whose very existence as scientists has required their transcendence of the stereotypes of our own cultural heritage. If the denial of difference between men and women has proved to be neither functional for women scientists nor realistic in its application, the denial of differences among men and women can certainly fare no better.

Notes

[1] Here differences between men and women are denied *a priori* political significance.

[2] In this, I lean heavily on Rossiter's excellent review, *Women Scientists in America*, on my research on the history of women at MIT (Keller, 1981), and also, where pertinent, on my own personal experiences as a woman scientist coming of age in the late 1950s.

[3] See, e.g., Rossiter (1982), Chapter 5, for further elaboration of this argument.

[4] Personal communication, Alice Huang, 1982.

[5] In practice, of couse, working scientists are well aware of the value of individual differences in talent and style. Only when such differences are claimed to be generic does this consciousness come into open conflict with the belief that the value and quality of scientific performance can be assessed by a single all-encompassing measure: how "good" is he or she?

[6] The story of Barbara McClintock provides a case in point (see Keller, 1983). Proud of her iconoclastic individualism, determined to transcend all stereotypes of her sex, she succeeded in fashioning a vision of science that stands in stark contrast to the prevailing vision around her. Her "difference" from her colleagues derived neither from her sex, nor from her female socialization, but precisely from her position as iconoclast and "outsider." As such, it serves to put into relief the particularistic values underlying the norms of conventional science. These values, I have argued, are not, as we have been taught, universal, but rather a heritage of the cultural equation between "scientific" and "masculine" that has helped shape the history of modern science. (For this last argument, see Keller [1985].)

Works Cited

Benbow, Camilla and Julian Stanley. "Sex Differences in Mathematical Ability: Fact or Artifact?" *Science*, Dec. 12, 1930. 1262-1264.

Cott, Nancy. *The Grounding of Modern Feminism*. New Haven: Yale University Press, 1987.

Keller, Evelyn Fox. "New Faces in Science and Technology: A Study of Women Students at M.I.T.", unpublished manuscript, 1981.

___. *Reflections on Gender and Science*. New Haven: Yale University Press, 1985.

Rossiter, Margaret. *Women Scientists in America*. Baltimore: Johns Hopkins University Press, 1982.

Traweek, Sharon. "High Energy Physics: A Male Preserve", *Technology Review*, November/December 1984, 42.

How Can a Humanist Compare Religious Classics?

Wendy Doniger O'Flaherty

What can students of the humanities gain by studying comparative mythology? I will argue that we do not have access to our own religious classics; that, contrary to expectations, we may have more access to other peoples' religious classics than to our own; and that there are good ways in which we can teach our students to assimilate the religious classics of cultures other than our own.

I will concentrate on myths, which are, I think, the genre of religious literature that has crossed cultural boundaries most easily. A myth's core of meaning survives to some extent even without language; the myth can be recreated again and again, reinflated like a collapsible balloon. The Trojan horse and the myth of Eden survive as myths, free-floating without words; the non-mythological classic, by contrast, survives only in language, despite the sustaining nature of the ancient core of truth that it embodies. As Claude Levi-Strauss has remarked, where poetry may be lost in translation, "the mythical value of myth remains preserved through the worst translation."[1]

Eliade has demonstrated how, even when myths become degraded, even when they may lose their power and even, on an overt level, their meaning, they always retain their intrinsic value, however much this may be disguised or forgotten.[2] Myths can be impervious to kitsch. In one sense, this is a good thing; if myth could not survive kitsch, some myths would never have survived at all. When the archetype is truly powerful, it does not need a powerful manifestation to convey it. An American company called "Impulse" markets small capsules called "Instant Mythology" that are literally *reduced* (and re-inflatable) myths: "Drop capsule in warm/hot water and watch mythological characters appear! Fun - educational - non-toxic. For ages 5 years and above. Not to be taken internally. Capsules contain: centaur, dragon,

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Pegasus, unicorn, or mermaid." Some archetypes seem to be able to exert their power in almost *any* manifestation.

But myth, too, is carried on language as perfume is carried on a wimd. Mary Douglas has challenged Levi-Strauss's assertion that myth can be translated, and has pointed out the ways in which myth, like poetry, cannot be translated after all.[3] When a myth is translated, its classic component is somehow tarnished; thus part of the Bible is invisibly lost to those who cannot read Hebrew or Greek and was invisibly lost to many people when the King James translation was discarded. For even a myth needs *some* linguistic detail, some spark of originality, to ignite it for us; it must eventually be re-inflated, re-tumesced, and if the language that attempts to do so is inadequate and unexciting, the myth will not come to life again. This being so, Levi-Strauss's assertion of the independence of myth from language is true only of a certain sort of myth, and then only partially true. Some myths do not survive some translations. As J.M. Cameron remarked of religious kitsch:

> I set beside "I come to the garden alone" the noble hymns of Isaac Watts and Charles Wesley and the former simply falls away from the world of authentic religious discourse, as do the holy pictures that used to -- perhaps still do -- punctuate the lives of Catholic children. I think kitsch presents us with a serious theological problem and stands, far beyond the formal bounds of theology, for something amiss in our culture as, for example, when well-washed fat babies or puppy dogs presented on the cinema screen evoke disproportionate cries of delight. Kitsch is a form of lying, and religious kitsch lies about what is, for the believer, the deepest reality.[4]

Most of our own Western myths now survive only on the level of kitsch; the real myths, in their classic forms, are no longer ours -- if, indeed, they ever were. We have long taken pride in the fact that our classics provide a shared communal base for all educated members of our culture. But this assumption is unfounded: we do not know our own classics. Even in the good old days (*in illo tempore*, as Mircea Eliade would put it), when everyone who mattered was able not only to read Greek but to translate editorials from the *Times* of London into Greek prose -- even then, the paradox of the classics was that they *excluded* rather than included people. The classics were the texts that *we* knew and *they* didn't. The classics defined a tiny elite who in turn defined The Community as consisting of themselves. Nowadays, of course, even that arrogant self-deception has been shattered. Only a tiny percentage of Americans read Homer even in English translation, let alone in Greek, and it is Dick Tracy and "Dallas" that provide what shared culture

we have.

The examples of Dick Tracy and "Dallas" are particularly apt, I think, because they belong to the genre of the serial, a Western parallel to the never-ending chain of stories that is taken up, link by link, night after night, by village storytellers in traditional societies like India. When Dickens published his novels in serial form, the English-speaking world would hang upon the next installment; it is said that when a ship docked in New York carrying the latest chapters of *The Old Curiosity Shop*, the crowd on shore cried out to those on board, "Is little Nell dead?"[5] A contemporary American serial novel has been likened to Dicken's serials by a writer who commented, "The experience of a serial is that of a common, contained world. It is a shared event. Everyone is reading or watching the same episode within the same time frame. No one can skip ahead until the next installment comes out. And that level of containment is important, for it provides the serial with its basic subtext: we are all in this together."[6] This is not at all a bad definition of the function of myth. Nowadays, this subtext exists primarily in soap operas on television. Yet we pride ourselves on having the highest literacy rate in the world. So much for the shared, communal base of our classics.

One reason why few of us can appreciate our classics is because they are, and have probably always been, archaic to most of us. Even Homer and Shakespeare, our classic classics, chose (or were constrained) to base their own works on other works that they inherited from a generation that was to them archaic. Indeed, it may well be that it is the very *nature* of classics to be other, to refer back to a lost golden age and to speak with an archaic diction that we must strain to understand. We sense instinctively that our classics were born long ago, in a galaxy far away. This means that we cannot possess our own classics, if by "possess" we mean to internalize, to experience as a familiar, non-other body of literature. This is true to some extent of Shakespeare, and even more true of Homer, who comes to us not only from another time but from another continent and in another language. Thus we must confess that our own religious classics are always in some basic ways other to us. Yet the classic is always relevant because, like Proteus, it always changes its shape to fit the needs of the moment.

Homer is the mediating point, the classic that we regard as our own but is in fact other; once we admit this, we have admitted that what we find classic in Homer is classic to us because it is felt to be *ours*, not because it is familiar but because it is *true* to *us*. And once we have granted this, we can begin to realize that the classics of the rest of the world may also be true and may therefore also be ours. And the very weakening of our moorings within our own culture may in fact be a source of our new ability to anchor ourselves to those other cultures. This is a fact upon which I and Allan Bloom agree, but whereas he thinks it is a bad thing, I think it is a good thing.[7]

For once we admit that our classics are not our own, we can begin to possess them in another way, a way that also makes it possible for us to possess a whole new world of classics, other peoples' classics. Moreover, once we are released from our expectation that it should be easy for us to understand "our" classics, we will be more willing to do the considerable hard work that is necessary to "translate" our own classics into our own language, instead of expecting them to be easy to read and discarding them in disappointment when the going gets rough. We will also be prepared to devote to other peoples' classics the additional hard work that is required to understand them.

It might be supposed that this work would be overwhelming, since the religious classics of other cultures are even more other to us than our own, other squared, as it were. I don't think this is the case. Though the otherness of other peoples' myths does indeed provide serious obstacles to our understanding of them, it also enables us to do a kind of end-run around some of the obstacles that stand in the way of our understanding of our own myths. Foreign myths tell us things that no one else knows, strange truths that are truly strange, things that our own myths never dreamt of. But they also sneak past our guard to tell us the things that we will not listen to from our own myths. The foreignness of the foreign text simultaneously mutes and intensifies the shock of recognition by presenting our home truths from an unexpected angle. For these reasons, other peoples' myths often affect us more deeply than our own myths do.

The myths of others may present to us truths that may indeed exist in our own culture but that we tend to ignore or undervalue or resist when we encounter them in their familiar form, prophets in their own country. We see ourselves with abrupt clarity in what appear to us to be the shockingly distorted images of "others", images of ourselves translated into "the wrong order" in the fun-house mirror of a foreign idiom. Myths constitute a stage on which we can see ourselves, not as others see us, but *as Others*. These images shock us, both because we see that they are like us and because we see that they are not like us. This seeming distortion allows us to realize things about ourselves that we did not or would not notice about the image that we saw in the mirror of our own culture -- a mirror that we could not bear to look into with our eyes wide open because, wrongly, we thought that our own culture held up to us an accurate mirror, a mirror that was not "other". In that mirror we saw ourselves as through a glass, darkly; in other peoples' mirrors we may see ourselves face to face. When we look at strange myths we miss the faces that are familiar to us from our own myths, but strange myths make us realize that the faces in our own myths are strange, too. They show us not only that what we thought was other is in fact familiar, but that what we thought was familiar is in fact other.

Other peoples' myths also tell us that what seems strange in our *own*

myths, and even in our most private dreams, may not in fact be so strange as we fear it to be. Once we have learned what is "other" about other peoples' myths, we are equipped to turn our lights back upon ourselves, to photograph the cameraman. By studying the myths of others, we may gain the consolation that comes from recognizing that others do not, in fact, think very differently from us in certain ways, particularly in ways that we are ashamed of or frightened by.

What may appear as a paradox, but is in fact a profoundly disturbing truth, is the fact that illiterate people often know their classics, while we do not know ours. But the loss of our own classical tradition may become a positive factor when we come to adopt *other* peoples' myths. Now we are not only freed *from* ritual (which we have lost) but we are also freed *for* myths. Now we can pick and choose our myths from the wide panoply of the myths that exist on the planet Earth, choosing them as individuals instead of inheriting them helplessly as part of an entire culture. Plato spoke of a supermarket *pantopoleion* of constitutions in Athens;[8] nowadays we have a supermarket of myths in which the individual can shop. For this reason, too, translations have become far more important and also far more easily available in the literary supermarkets of bookshops.

There are two complementary types of eclecticism that may enable us to assimilate both our own classics and the classics of others. Through the first of these methods, any one of us can make any single classic our own. At the end of Ray Bradbury's *Farenheit 451*, when all the books in the world have been burnt, a group of people gather around a campfire; each of them has memorized one of the classics and so thoroughly internalized it that when they are introduced to one another one can say, "Hello. I am Plato's *Republic*," while a man named Harris in Youngstown is The Book of Ecclesiastes.[9] This form of assimilation is very rare in our day; not many people memorize, or even internalize, a whole book. But in ancient India, people really did memorize entire books of the Vedas, and they became known as the living incarnation of one particular school or branch (*shakha*) of the Vedic tree.

But just as an entire classic can become part of all of us, so too, parts of the classics have become part of any one of us. There is the old story of the woman who went to see *Hamlet* for the first time, and afterwards was asked what she thought of it. "It was quite good," she said, "but it did have an awful lot of quotations in it."[10] Many of the people who tell us that brevity is the soul of wit or that there is method in our madness do not know that they are quoting *Hamlet*. Indeed, the very fact that I am able to make this joke about *Hamlet* is evidence of its classic status. For, to paraphrase a statement by G.K. Chesterton, one test of a really good myth is that you can make jokes about it.[11]

A more poignant instance of this process of assimilation was noted by

Hannah Arendt, who told of a concentration camp in World War II in which people got together and each tried to remember as much of Homer as he or she could, to piece together all the pieces that they knew. They did not manage to reconstruct all of Homer; and so their work did not keep Homer going, as it were (the way the whole work was preserved in the fiction of *Farenheit 451*); but they did it because it "kept *them* going," she said.[12] The pieces of Homer in them were things they clung to when all the rest of their civilization was destroyed.

Thus, a classic may be preserved either through an individual eclecticism (the *Farenheit 451* model, each classic going into a fragment of society, a person), or through a cultural eclecticism (the *Hamlet* quotation model, the fragmentation of the classics, each piece going into all of us, into society as a whole.)

The Bible, possibly only true classic we have left, is the only one that is preserved in both of these ways to any significant degree. That is, almost all of us know some of it by heart. The pious hope that everyone should be able to understand the Bible in church led to the great translation into English under the sponsorship of King James. But for most of us (those who know only some of it), the Bible as a whole functions only as a piece of ritual, in church; we tend to preserve this aspect of the Bible in what has now become an archaic form, the very King James translation that was meant *not* to be archaic. The realization that we tend to confuse our favorite archaic version with the Ur-text was expressed by the man who is said to have remarked, "If the King James version was good enough for Jesus, it's good enough for me."[13] And many people confer yet another divine sanction upon this text when they misname it the Saint James Bible.

When attempts are made to remove the archaism of the King James Bible, both because its diction is difficult for many Americans to understand and because we now know that much of it incorrectly translates the Hebrew and Greek, we are troubled. On the other hand, the very fact that most of us do not know the Bible thoroughly makes it possible for us to take the *text* of the Bible (that is, the Bible as myth, or sacred narrative, rather than as a piece of ecclesiastical ritual) and to redefine that text as a true classic, acknowledging its otherness. In this way we may begin to re-approach the Bible and to re-possess its meanings outside of our own particular ritual context. We may be able to study it as humanists, as if it were someone else's religious classic, someone else's myth.

But relativism, as Allan Bloom has brilliantly demonstrated, also has its disadvantages. How can we find a single truth in the midst of multiple meanings in many myths from many different cultures? The value of seeking several versions of "our" myths in cultures other than our own may be illustrated by a story. It seems that two Irishmen, Paddy and Mike, were sitting all day in a duck blind, drinking from a jug of Poteen (a kind of potent

Irish moonshine, home-made whiskey), waiting in vain for the ducks to appear. At last, when both the daylight and the poteen were gone, a single duck flew across the evening sky. Mike groggily raised his gun and fired a shot, and the duck fell like a stone at their feet. "By God, Mike," said Paddy, "it's little less than a miracle that you could hit that duck in the state you're in." "But surely, Paddy," said Mike, "I'd be able to hit one single duck when the sky is full of the hundreds of them."

To me, this story is a kind of Irish koan or Zen shaggy dog story. The Irishmen are hunting the wild goose of truth.[14] And since they think that the sky is full of ducks, they hit one -- *even though there is really only one duck.* (Contrariwise, people who think that there is only one duck in the sky may never be able to hit it.) This parable argues for the reading of the myths of many different cultures; and it suggests that even if you believe that there is only one true answer to any great human question (a foolish belief, I think), you are more likely to find it if you shoot at a number of ducks -- if you take seriously a number of different cultures' answers to that question. There are so few interesting questions, and so many interesting answers.

The story might also be taken as a parable for another kind of eclecticism, the use of many different theories in attempting to understand any single myth or all myths. If one can ask many different good questions about any single myth, and one can answer any of these questions in a variety of good ways, it makes sense to try several different approaches -- structuralism, Freudianism, Marxism, the usual gang. A thick theoretical description of a myth (to use Clifford Geertz's phrase) immerses the myth in a solution supersaturated with potential meanings (the only "solution" that a myth can have). Then, anyone who reads that description can lower into it the string of his own questions -- can go fishing for answers, in the hope that his own meanings will crystalize around his questions.[15]

The single duck may be the true answer, the answer corresponding to the archetype, the One, the monotheistic pantheon; but the flock of ducks are the multifaceted illusion that makes life possible (*maya*), the manifestations, the Many, the polytheistic pantheon. Both the myth and the archetype value themselves for the unique situation of each one in its own single culture; but both of them also value themselves for their ability to capture a universal truth. The unique situations form, with all the other unique situations, a flock of separate geese; the universal truth is the One Wild Goose.

Notes

[1] Claude Levi-Strauss, *Structural Anthropology*. (New York: Basic Books, 1963), 210.

[2] Mircea Eliade, *Patterns of Comparative Religion* (New York: New American Library, 1958), 431-434.

[3] Mary Douglas, "The Meaning of Myth, with Special Reference to 'La geste d'Asdiwal,'"

pp. 49-70 in Edmund Leach (ed.), *The Structural Study of Myth and Totemism* (London: Tavistock Publications, 1967).

4 In *The New York Review of Books*, May 29, 1986, 57.

5 Cited by Marcia Froelke Coburn, in *Chicago* magazine (April, 1985), 130.

6 Marcia Froelke Coburn, in *Chicago* magazine (April, 1985), 130.

7 Allan Bloom makes a brilliant case against relativism in *The Closing of the American Mind* (New York: Simon & Schuster, 1987). We agree upon the problem, but we disagree about the solution. This paper is, in part, an attempt to propose and defend my solution.

8 Plato, *Republic* 557d.

9 Ray Bradbury, *Farenheit 451* (New York: Ballantine, 1953), pp. 163-165.

10 David Greene told me this joke.

11 Chesterton said that this was the test of a really good *religion*.

12 Hannah Arendt told this to David Greene, and he told it to me. It may also be recorded somewhere in print.

13 This is apparently a very old and well-know joke, but I first heard it from Bill Graham on February 25, 1986, so I am indebted to him for it.

14 Virginia Woolf uses the wild goose as a symbol for the elusive truth in her novel, *Orlando*.

15 The value of eclecticism in method may also be stated negatively: if the only tool you have is a hammer, every problem becomes a nail. There is, fortunately, a story about this, too: A drunk was staggering around under a lamp post, looking for his keys; a policeman stopped to help him, and after a while, when they didn't find the keys, the cop asked the drunk, "Are you sure you dropped them right here?" "No," said the drunk, "I dropped them across the street." "Then why are you looking for them over here?" asked the cop, rather grumpily. "Because the light is better here," replied the drunk. An eclectic has lots of lamp posts to look for things under.

Creativity and the University -- A View from the Piano

Sharon Mann-Polk

I am a musician. In my field -- piano performance -- the traditional paradigm for nurturing artistry (*cum* creativity) has depended mainly on a mentor-disciple arrangement. What can come from this bewitching arrrangement is an inspiring one-to-one relationship with a role model, the development of a strong ego, and importantly, a taste for what I call "work-play".

The ideal mentor in this system creates an atmosphere of both stability and change in the presence of random noise. Imagine a kind of glorious tension between learning what already is and learning to want to move in a direction one cannot go. Imagine inspiring in a student the taste for both the plausible and the implausible. In this private and coveted arena, it is the teacher who subtly communicates these values, who co-mingles a call for mastery with a call for experiment, who imparts a dual respect for order and disorder, who encourages discipline and honors the hunch, who builds, and who tears down.

While this arrangement is not immune to abuse (it can camouflage a quack or crush an apprentice into servitude), it does work. Given a good teacher and a talented student, it can spawn an artist. Most of the world's great musicians have been bred in this environment.

A pattern is witnessed from the earliest years of training in this system: the disciple, from childhood, experiences both immersion and exploration, both preoccupation and prospecting, both the rational and the intuitive. A kind of inner prescription for the dosage comes early. Children signal when they have had enough theory, when they need to explore. Children know with absolute certainty when they must stop observing the thing and *be* the thing. Their innate model is work-play. I think of this as a

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mastery/movement paradox because of its innate and apparent contradiction.

The music student in this paradigm learns to respect the facts about the page of Chopin before him; but he is encouraged to listen also to what are his dim notions, his vague feelings; he is authorized to reshuffle the patterns, to search for his own voice. The future artist cuts his teeth on paradox.

Every act has a past; invention comes into play only after we have absorbed the facts, the histories, the techniques. Creative work involves a flaring of insight, a sudden recognition of a previously hidden relation or a new possibility. In every case, the pathway into the creative act is private and personal - a quirk.

Arthur Koestler, in his book *The Act of Creation*, calls this kind of creative act "bisociation,"[1] the placing of a familiar problem in an unaccustomed context, without losing sight of its original context. Archimedes, so the story goes, was baffled by the problem of assaying the gold content of the tyrant Hiero's new crown; in search of relief, he visited the local bath, and in a flash of bisociation he saw -- as if for the first time -- the familiar rising of the water displaced by his body in terms of the problem that had been gnawing at him. The difficulty was solved in an instant; all that it took was a new way of looking at it.

Pythagoros, they say, found his law of the relation between musical tone and string length as he passed the local blacksmith's shop one day. "Ping! Ping! Ping!" tapped the smith on a small bar of metal, then "Pong! Pong! Pong!" on a large one. Pythagoros' moment of bisociation led him to apply some intuitive geometric reasoning to this everyday phenomenon (which must have seemed far removed from geometry at the time). Undoubtedly, in scientific fashion, he formed an hypothesis on the spot and went home to test it. Octaves, he found, occur in vibrating strings in length ratios of 1:2; thirds, fourths, and fifths, with their pleasing consonances, in ratios of 4:5, 3:4, and 2:3. And so on through the several intervals of folk melody. Whole-number ratios! This conception of geometry in the primal workings of the world was one of the most far-reaching and pregnant of all time. I am proud to claim it for the world of music. (It's quite a pleasant vision, to imagine the great Pythagoros plunking on some primitive banjo or lyre -- especially if one is familiar with the enormous intellectual elaboration those first expermients have received in the intervening centuries.)

It is a curiosity why the master-disciple system has been a most enduring and successful mode for cultivating the mastery/movement paradox. Perhaps this is because the master-disciple system is fundamentally an intimate place, a place where the disciple can be utterly known. Humanistic psychologists, concerned more with creative process than creative product, refer to this sense of uniqueness, this feeling of being known, as "individualization". Carl Rogers, for example, touches on individualization in his definition of the

creative process:

> . . . the emergence in action of a novel relational product, growing out of the uniqueness of the individual on the one hand and the materials, events, people or circumstances of his life on the other.[2]

An intriguing study by educational researcher Benjamin Bloom observed one hundred concert pianists, Olympics swimmers, tennis professionals, and research mathematicians, all of whom reached the top of their fields before the age of thirty-five. Despite the disparity of fields represented in the study, Dr. Bloom identified patterns in early development common to all achievers: 1) early identification of talent; 2) extraordinary parental/family involvement and dedication; 3) an increasingly demanding schedule of one-to-one tutorings; 4) gradual intensification of practice to the eventual exclusion of all ordinary distractions.

Dr. Bloom's observation from this study was that it was "nurture" rather that "nature" that was the deciding factor in the development of these extraordinarily creative achievers. "No," said Bloom, "genius will *not* out."[3]

Creative acts, it seems to me, conspire with irrationality, with the implausible, with unchartered waters. One must unzip one's mind and unfocus one's eyes, allowing the hard-won mastery of technique, of structure, to fade out of conscious sight -- to blur into the spirit of play, of imagination. Frank Barron puts it this way:

> The creative individual . . . is likely to have more than the usual amount of respect for the forces of the irrational in himself and in others. This respect consists in a faith that the irrational itself will generate some ordering principle if it is permitted expression and admitted to conscious scrutiny.[4]

Witness, for example, the odd practicing habits of the gifted, eccentric pianist, Glenn Gould.[5] Gould placed "totally contrary noises as close to the instrument" as he could, an admittedly unconventional habit that began when he was thirteen or fourteen and happened to be practicing one day when his mother's vacuum cleaner flared up. His Mozart, Gould found, sounded much better to the accompaniment of his mother's vacuum cleaner. "Those parts that I couldn't actually hear sounded best of all," he wrote later. "The inner ear of the imagination is very much more powerful a stimulant than is any amount of outward observation." In adulthood, Gould found he could generate his own irrational noise by playing rock and roll or television westerns . . . "anything loud will suffice" . . . while committing new sources to memory.

The Gould vignette testifies that the artist's relationship with his work begins early. By the time nascent artists matriculate as college freshmen, they have already experienced considerable training, mostly in the mentor-disciple system. For many, a deep relationship with their work is already in place and has been for years. Many are already at the crossroads of deep self-actualization. The institution must be ready for them.

Most practitioners of the arts can recount from their history the few private, pivotal moments that were turning points in their development. One such moment happened to me in the music conservatory I attended.

Half-way through my freshman year, my teacher gave me a lesson that changed my world. Actually, it was a *non*-lesson. I had been working up a Bach Prelude and Fugue. One day, after two lessons on the work, my teacher pronounced it fit. "Put it away," he said, "and begin to work on the Ravel concerto for next week." I was stunned. For me, the Bach was raw, unfinished, almost terrible. Yet here was my mentor, dismissing it, calling it very good, announcing that our work on it was complete. I knew very well that it was *not* good, but I did *not* know what "better" was! There it was, a crisis. I needed to move in a direction I could not go.

I had no idea what to do. I remember being in tears when I slipped into my practice room, locked the door, shut out the lights and began slowly to play the work on the piano. Slowly, over and over, in the dark. I don't remember when it happened but somewhere, perhaps the next day, I became plagued by the notion that the thinnest membrane separated me from honestly hearing the heart of the music. I began to miss classes, to spend whole days there, shut away from the world in that quiet, dark place, playing the work over and over, listening, listening. In the end, I spent two weeks there. Two weeks locked in a dark room, experiencing countless random interactions with one short piece of music. All the while, it must be mentioned, the institution to which I was responsible and which was responsible to me, knew about these peculiar goings-on and did nothing to stop them. In an act of profound trust, the system left me alone.

In time, something happened. The music came alive, began to "speak." I experienced a deep, affirmative knowing of it. It became non-negotiable. It *was*, in the way that one's arm *is*. I remember a feeling of order emerging from all that terrible randomness, from those infinite possibilities. I remember notes uniting into a being, into a finality . . . non-negotiable, permanent. When I left that absurd little cell two weeks later, I was in fact, profoundly changed. I had been alone *really*, with this thing; I had taken the first small step to leave my mentors; I had moved in the direction I could not go. I was on my way.

I tell this story for two reasons. One, I believe that many years in the work-play mentor-disciple system had primed me for that critical episode. I suspect that it was not so much the magnificence of my teachers as much as

the highly-personalized mode itself that galvanized the ego strength necessary to embrace that challenge. I believe I had not been merely *taught*, but that I had been *encountered*, and it was in those uniquely personal one-to-one tutorings that I grew strong, became acquainted with irrational process, learned to have faith in hunches. In other words, I believe that it was the unique training of my youth that pitched me later, as a young adult, into a dark room for two weeks with no agenda whatsoever except some lonely, cosmic itch.

The second reason for telling this story is that I believe this pivotal moment in one professional life simply could not have happened were it not for the fact that the educational system to which I was attached -- in this case, a music conservatory -- actually *sanctioned* my two-week hiatus from an orderly learning mode.

The writer Rilke "sanctioned a two-week hiatus in a dark room" when he wrote the following letter to a young poet:

> You ask whether your verses are good. You ask me. You have asked others before. You send them to magazines. You compare them with other poems, and you are disturbed when certain editors reject your efforts. Now (since you have allowed me to advise you) I beg you to give up all that. You are looking outward, and that above all you should not do now. Nobody can counsel and help you, that bids you write; find out whether it is spreading out its roots in the deepest places of your heart, acknowledge to yourself whether you would have to die if it were denied you to write. This above all -- ask yourself in the stillest hour of your night: must I write. Delve into yourself for a deep answer. And if this should be affirmative, if you may meet this earnest question with a strong and simple 'I must,' then build your life according to this necessity; your life even into its most indifferent and slightest hour must be a sign of this urge and a testimony to it . . . And if out of this turning inward, out of this absorption into your own world verses come, then it will not occur to you to ask anyone whether they are good verses . . . for you will see in them your fond natural possession, a fragment and a voice of your life. A work of art is good if it has sprung from necessity. In this structure of its origin lies the judgment of it: there is no other.[6]

Glenn Gould, who, by the way, could never summon the courage to teach, had the following advice for teachers:

> . . . your success as teachers would very much depend upon the

> degree to which the singularity, the uniqueness, of the confrontation between yourselves and each one of your students is permitted to determine your approach to them. The moment that boredom, or fatigue, the ennui of the passing years, overcomes the specific ingenuity with which you apply yourself to every problem, then you will be menaced by that overreliance upon . . . the system.[7]

Is creative process, as I have shown it, antithetical to educational process? Is there some fundamental dichotomy between the activities, for example, of the artist and those of the scholar?

Perhaps the answer lies in academe's current trend of professional graduate programs in the arts. For the past several decades, academe has become increasingly committed to the training and the certifying of artists. The artist, for his part, is apparently seeking what Walter Eels calls "a testimonial of his skill" by acquiring academic degrees.[8] An interesting case in point is the plethora of terminal degrees in applied music.

Beginning in the 1950's with the development of academe's first professional doctoral program tailored to the performing musician and advancing through the "cultural boom" of the 1960's, American universities, with their customary alertness to social trend, have developed advanced programs and curricula for the performing musician.

The most zealous supporter of these programs was Howard Hanson, then Director of the Eastman School of Music. He favored the idea of a professional doctorate based on musical practice as well as musical scholarship, and in particular a degree providing its recipients with academic rank equal to that of the musicologist. Dr. Hanson believed that an educational system that supported the study of the history of an art but frowned on its practice would violate "not only a basic educational philosophy but the fundamental unity of the art as well."[9]

Dr. Hanson's view was, as may be expected, opposed by many scholars trained in the humanistic tradition. James Ackerman expressed these qualms:

> The invasion of the arts on campus is problematical because the mission of scholarship and the mission of the arts are antithetial.[10]

McNeil Lowry went further:

> . . . the best service you can perform for the potential artist is to throw him out . . . no play was ever more dramatic, no musical composition more evocative, no novel truer to the

imagination, merely because its author was given a Ph. D. for creating it.[11]

Among the dissenting voices, the most persistent was probably that of Paul Henry Lang, eminent musicologist and then editor of *Musical Quarterly*. From 1949 through 1953, Lang wrote a series of editorials in journals and newpapers expressing his position that the university is not the place for training performers and that, in fact, a doctorate in performance is a contradiction of terms.

In one heated place in the *New York Times*, Lang wrote:

> Now we are able to have doctors of playing and singing. I can very well see what this will mean: an earnest violinist who spends all his time on improving his art and consequently won't have the time to seek a 'doctorate', will be left behind by some ersatz fiddler who, by obtaining a questionable degree, will be acceptable to some august college in preference to the more accomplished artist. When the conservatories feel the pinch of competition thus created for their graduates, they too will establish a degree factory and turn out doctors of piccolo playing and duo pianism.[12]

The sharp juxtaposition of these opposing views demonstrates that professional training of artists in academic institutions is a question germane to an inquiry into the possibilities for teaching creativity in the university of the future. The central issue here is whether the rigorous demands of artistic development can be fully served while preserving the mission of scholarship.

Some light can be shed on the subject by looking at how these professional programs have fared. The fact is that the arts and humanities have been placing 85% to 90% of their doctoral recipients in college and university teaching positions.[13] There is, of course, nothing wrong with training qualified teachers and scholars, and we may even presume that those matriculating into these professional programs have in mind university careers. At the same time, the conclusion is inescapable that, regardless of intent, the professional graduate programs in the arts have not been a significant producer of performing artists.

I find the statistics above worrying, particularly so if they are telling us that future artists are being transformed into professors in a sort of academic *perpetuum mobile*. The risk, in my opinion, of imposing on artistic training the conditions of humanistic scholarship, is that academe may well create a kind of artistic factotum, and also devalue the meaning of the doctorate. In my fantasy, I imagine a world where graduates in professional arts programs who anticipate careers as educators are trained in teaching programs; where

artists who anticipate professional performance careers receive professional training separately from graduate work; where universities eliminate degrees in the applied arts beyond the B.A.; and where advanced degrees as criteria for appointment and promotion in the academy are ignored.

"The trouble begins," Gould wrote:

> . . . when we start to be so impressed by the strategies of our systematized thought (about music) that we forget that it does relate to an obverse . . . . When people who practice an art like music become captives of those positive assumptions of system . . . they put themselves out of reach of that replenishment of invention upon which creative ideas depend, because invention is, in fact, a cautious dipping into the negation that lies outside system from a position firmly ensconced in system.[14]

Shall we conclude from all of this that because the bird died the air was foul?

Probably not. In many fields, the university has successfully fostered creative individuals (for example, all American Nobel Laureates in the hard sciences) through advanced degree programs for which the traditional paradigms of humanistic scholarship are both relevant and internally consistent. Unfortunately, attempts to force an equivalency between certain creative and scholarly endeavors may be doomed to failure because of the inherent differences in the fundamental paradigms that apply to them.

In the large sense, the question of fostering creativity remains a challenge. Although the perspectives given here from the limited viewpoint of a performing pianist cannot be generalized without some risk, they do point in a clear direction. The university, rather than falling prey to an overreliance on system, rather than imposing its certificates, needs to foster a more contextual approach, keeping in mind the arrangements and practices that have nourished creative people. The university will need to search continually for effective ways to encompass these arrangements and practices into the evolving university environment. Academic goals, credentials, and curricula in advanced studies should be carefully tailored for the needs of specific disciplines and professions, and not forced into a one-size-fits-all mode. One system, the mentor/disciple arrangement, will remain a primary well-spring of creativity, and the university needs to adapt this system to advanced studies generally, in ways that will allow and stimulate our future students to thrive and develop within the paradox of mastery and movement, which I believe is basic to human creativity.

Notes

[1] Arthur Koestler, *The Act of Creation* (New York: Dell, 1964), 35.

[2] Thomas Busse and Richard Mansfield, "Theories of the Creative Process: A Review and a Perspective," *Journal of Creative Behavior*, 14, 2 (1980), 96.

[3] Maya Pines, "What Produces Great Skills? Specific Pattern is Discerned," *The New York Times*, (March 30, 1982), 21-23.

[4] Frank Barron, "The Psychology of Imagination." *Scientific American* (September 1958), 150-169.

[5] Tim Page (ed.), *The Glenn Gould Reader*, (New York: A. Knopf, 1984), 6-7.

[6] Rainer Maria Rilke, *Letters to a Young Poet*, trnas. M.D. Herter Norton, (rev. ed. New York: W.W. Norton, 1954) 17-22.

[7] Page, 6.

[8] Walter Eels, *Degree in Higher Education* (New York: Center for Applied Research in Education, 1963) 8.

[9] Howard Hanson, "Music in Contemporary American Society," *Montgomery Lectureship on Contemporary Civilization*, (Lincoln: University of Nebraska Press, 1951), 42.

[10] James Ackerman, "The Arts in Higher Education," in *Content and Context*, Carl Kaysen (ed.), (New York: McGraw-Hill, 1973), 227.

[11] W. McNeil Lowry, "The University and the Creative Arts," *Educational Theatre Journal* 14, 2 (1962), 112.

[12] Paul Henry Lang, "Letter to the Music Editor," *The New York Times*, (November 1, 1953), Music Section, 9.

[13] Paul Palombo, "The Future of the Doctorate in Music: Significance and Alternatives." *Proceedings, NASM*, (1979), 309.

[14] Page, 5.

The Faces in the Wall

Kate Wilhelm

No field can survive without its creative innovators -- science, history, philosophy, and so on -- but my remarks about the creative act itself will be largely restricted to the creative arts. Because I am a story teller, it is appropriate that I tell you some stories. There was a little girl, six years old, in the first grade, who wriggled with excitement on this particular night, parents' night at school. The big production of the evening was an art show. One by one the children went to the front of the room to display their drawings and then stand them on the chalk tray of the blackboard as the parents applauded. The little girl went forward at her turn and showed her picture, a farm scene, with white buildings, a red barn, and a purple fence. As she stood up her picture, the teacher said very kindly, "But, dear, we know, don't we, that farmers don't paint their fences purple." The little girl was crushed, humiliated, and no doubt turned off art for the rest of her school career. Possibly for the rest of her life.

Another time. I was one of three judges for a state-wide high-school competition in creative writing. There were over a hundred fifty stories submitted, from which six were to be chosen for a one-week workshop with a professional writer. Up to a point it is not difficult to choose among them. The vast majority are easy to reject. I always try to end up with ten stories, several that I am willing to fight for, and several where the differences are slight. Our judges met to discuss the entries, to pick our six. Since I was to conduct the workshop, I had a great interest in the selection process. One of the judges, the state superintendent of schools, named the top story on his list and for a time I thought he had read a story I had not seen. I dug it out of my stack of rejected manuscripts and I was horrified. It was a piece of rifle-association propaganda. We talked about it, but until I went over the

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manuscript and pointed out the clichés and the actual phrases lifted from NRA material, he was not convinced that it should be rejected. Even then, he did not fully approve of the final choices; he thought too many of the stories were unwholesome, the young writers too preoccupied with sex, death, drugs, war, and so on.

More. At a conference a high school senior asked me to read his story. After I read it, I called him aside. I asked where he had got the story and he answered without hesitation that he had seen it on television. He named the series which I had never heard of. But I knew. The story was obviously from television; the manuscript even had the blank spaces where the commercials were to go. My surprise came from his ready acknowledgement of the source. His teacher had graded the story A-plus.

Another child used only black and brown crayons for his drawings, great globs of black and brown. Ah ha! Off to the school psychologist with him.

One boy, fulfilling an assignment to draw a family group, found it impossible when he came to his mother's feet and tried to draw high heels. I sympathize; I can't draw feet either. He ended up putting black boots on all the family members. He solved his problem, but he was sent to talk to the school psychologist, also. He never drew anything again.

What is going on here? This is all anecdotal, but I am convinced that it is no more than the froth at the edge of the sea, and there is a vast ocean of ignorance and fear out there where creativity is concerned. The teacher who felt it necessary to deny that farmers might paint their fences purple was gentle and deadly. She was saying, in effect, you must conform to the correct world view, but this is the last thing that true creativity does. It is hard to imagine a more antithetical pair than creativity and conformity.

The superintendent was comfortable with a story that expressed his own political views, and very uneasy about those that asked hard questions about the world. The boy who wrote the gun story is being rewarded for something other than his creativity.

Even if the teacher of the boy who plagiarised television never saw TV, she should have known what he was capable of writing; she should have suspected that the story was not his original work. Any writer, any editor would have spotted it. And the boy thought it was all right because no one had ever told him original work was required. He is inundated with copies, imitations, derivative works all the time, in movies, on television, in paperback books. Our culture often rewards the derivative writers more than the ones who produce the original work. On what basis should he have made the assumption that "Thou shalt not steal" is valid in the field of creative writing?

There was a girl who was a gifted musician and composer, and who was diagnosed as having adolescent schizophrenia. During her normal periods she created wonderful music; during her episodes, she saw faces in the wall.

They were terrifying; she could not control them, make them go away, and they threatened to consume her with their great gaping mouths. Her music was meticulously controlled; it had context. The faces in the wall were beyond control; there was no context.

The little boy who used only black and brown crayons, if questioned by an artist, or someone who understands the process of art, might have revealed that he was afraid of shadows, of darkness, and he was trying to control fear through his drawing. There was context. He would tell the school psychologist nothing because he had been frightened, punished, belittled.

He had discovered one of the many riddles of art, that it can be used to understand the world, perhaps even to control the world to a certain extent, certainly to question the world. It is well recognized that any art form can be effective in therapy, but only when it is done openly, with full awareness, and great care. To use this child's art this way was to betray him, an act of cruelty, and it was one of the myriad ways we have to stifle creativity. Our society demands to know and approve the context. If we don't grasp the context, the artist, the writer, the musician is guilty of seeing faces in the wall and must be cured.

It might be argued that these are isolated instances of having the young writer/artist come in contact with the wrong person at the wrong time. That is a reassuring thought which I totally reject. Anyone who works within our schools whether from a safe-tenured position, or on the periphery, as I do, can tell similar stories again and again. Even if these were isolated incidents, it is ostrich-like not to realize the impact they have on the other students. They know who is being rewarded, who punished and humiliated, and they know why.

It is argued that there are not enough qualified teachers for all the specialized areas of education, and I agree. But few institutions would pick names out of a drum and hand out academic teaching assignments on that basis. Mr. Jones, you will teach history this year. Ms. Smith, you teach biology. Yet in all the arts that seems to happen. The daughter of a friend plays the violin; when she moved to a new school, there was no orchestra; band was taught. The girl enrolled. One day the teacher asked her to tune a violin he had unearthed. To her surprise she saw that it had no bridge, and when she told him she could not tune it because of that, he said, "Well, just do the best you can." Appreciation courses and theory courses do not prepare anyone to teach the most basic necessities in the actual creation of art. An opera lover would not be expected to teach the oboe player, or the flutist, or the soprano how to execute tl performance.

There is a dilemma. We understand the importance of nurturing originality, creativity, but we seem to do our utmost to strangle it at a young age. We rely more and more on quantifying creativity; we develop methods -d tests that anyone can apply in order to measure others, and we make

graphs, and charts, and select gifted students accordingly.

Anyone can follow the directions: show the students a brick, and ask them to think of as many ways as possible that a brick can be used. One student finds eight ways to use a brick, another finds ten, another only four. This is creative problem solving, but we should not confuse it with true creativity. It isn't necessarily. The little girl with the purple fence might be uninterested in bricks. The little boy coping with shadows might find this kind of puzzle boring. True creativity furnishes its own context and seldom is quantifiable; it is unreliable, unpredictable, and often it takes a giant step into the dark, into the unknown, where the context is not readily perceived by the one doing the testing.

There is always tension between a society that requires a steady-state condition and those within it who have a need to examine and test the boundaries. True creativity questions the *status quo*. Even that statement is enough to make lips tighten, attitudes become firmer in opposition to allowing such a thing. Creativity pushes against the boundaries, but society feels safe and comfortable when it knows where the boundaries are and that they are secure. Creativity changes the way we see the world, the way we experience the world; it enlarges and enriches the world. But tampering with reality, changing the world threatens everyone; who knows what new world will emerge? The little girl is testing reality by asking, " why not paint fences purple?" And the teacher is protecting herself, her understanding of reality, by saying we know they don't do that. Another piece of the boundary has been secured.

Writers change the way we use language, the way we think, even the things we think about and discuss. Artists change the way we see, what we see. Every original, creative act brings forth something that did not exist before, sometimes good things, often not such good things, but we must allow all of them to pass into being, not stifle them in an early stage out of fear. We must allow all of them to pass into being, not stifle them in an early stage out of fear. We must allow the artist to decide the context, and not conclude arbitrarily that artists, creative people in any field, are guilty of the faces-in-the-wall syndrome. History is too replete with instances of how society distrusts its artists -- Stravinsky, Lawrence, Van Gogh, Joyce, Ibsen. The list goes on and on. They dared to say the unspeakable, to examine the taboo, to question reality, and their contemporaries said no resoundingly. The ones we can name prevailed; how many gave up we can never know. The nay-sayers start long before there is a play under production, long before the artist is starving in the garret; the process of rejection begins early in elementary school, or even before school.

Can creativity be taught? No. And there is no need. It is all around us in the youngest child onward until it is frustrated to the point of extinction. A more valid, or at least more interesting, endeavor might be to try to learn

how some people escape the procees of extinction. By all means, we should encourage creative problem solving; we should encourage our young people to look beyond the obvious to find new and interesting ways of manipulating materials, the bricks, whatever other puzzle pieces we can devise, but that should be done in a room not labeled art or creative writing. We should be more rigorous in teaching expository writing, how to develop ideas for essays, how to do research without copying the encyclopedia, how to write when given the context. And that should not be called creative writing. Few people would call a paint-by-number picture art; write-by-number is no more so.

Should creativity be taught? Again no. And for an even more important reason: we don't know what it is. There is little understanding of how it works, even though there are and have been many theories. There was the theory of the old and the new brain, largely abandoned now. There is the Muse, a giver of creative impulses. There is the collective unconscious. There is the bicameral brain theory, the silent brain, and the brain with language to express the symbols and feelings the other side produces. With artificial-intelligence research pushing against the boundaries there is now more investigation than ever taking place in an attempt to understand the workings of the human mind. Computers can write poetry, follow plots to produce simple stories, and so on. But computers can't supply the context, the programmers do. No computer could paint great brown and black blobs in an attempt to master fear of the dark.

Among writers, the process of writing a novel varies so much that it is almost as if we are talking about totally different activities. At a workshop when I described my own method, one of the young women, a college graduate, was infinitely relieved. Her method was similar, but all through school she had been told repeatedly that she could not use that method. She had to outline first, prepare a summary, a first draft. She had stopped taking creative-writing classes because she could not work that way. Neither can I. I have never outlined a thing in my life, until after it was written, to satisfy a teacher. Usually writers don't talk much about how they produce stories or novels. We have all learned to beware of the faces-in-the-wall reaction of our audience. Today, however, I do intend to describe my method, to reinforce my firm conviction that it would be a mistake to try to teach it to anyone else, or to insist that it is the only way.

First, and I am choosing my words carefully, I have the feeling of a shape. This is not a shape that has a name, and it is not something that I can describe beyond saying that it is a container. It exists in my mind in many dimensions, and it is quite real in my mind. It is my task to fill it with a story, or a novel. I know when I have this shape in my mind that I will write something. The next step in this process is to wait for a very strong image that has a powerful emotional content. Often the image is of a person, or

more than one person. These are never people I know or have seen anywhere. Strangers walk into my mind, and I feel something very deeply about them, sometimes sorrow, sometimes joy, bewilderment, love. This emotion is attached to the image. Again I wait, for another image this time. If one is not forthcoming, I work with the one I have already. I question it. I try to force the people to reveal something about themselves. I look past them, around them to see if anything else is present, and worry with that. A room, a meadow, a train station, whatever it is. I have constructed entire houses by expanding this first image, whole neighborhoods, towns. Sometimes when nothing is working very well, I ask who sees this image, and I find that there is another character and it is through those eyes that I am seeing anything at all. Eventually I have a second image which I work with in exactly the same ways, and then a third one. I try to find out why the original image had that particular emotional value. The images begin to expand into scenes that suggest other scenes.

At some point I realize that I have enough images to fill the container that is no more than the feeling of a shape. Only now do I know if I am working on a novel or a short story. It could be argued that since thoughts don't have substance they can't fill a container, but I do fill it, and I know when it is full. I still don't know what the work will be about, what the story line will be, but I do know what emotional impact I am after. Some of the questioning and answering I do suggest research. I read a book about San Francisco perhaps, and that suggests something else, and something else. The very last thing I do is link the images and scenes in such a way that I can tell a story. Until I have done all this mentally I may not write a word, although I probably will have made maps, the house plans where my characters live, notes from the various books and articles I have been reading. When I know the story finally, it may be that my original image is in chapter ten, or the final scene of the novel, or perhaps in the opening. Now, with all the details in place, with all the characters revealed to me, the background researched, the story worked out from beginning to end, I start to write.

This is just one of the many, many methods of writing fiction, which is generally accepted to be a fairly creative process. I would be truly insane if I tried to force anyone else to work this way, and I would have to stop writing fiction if I had to work a different way.

There are many problems to be solved in writing anything. How to get from one image to another, what scenes mean, what actions mean, how to move a character from one scene to another. These are problems that arise within the context of the piece of work, and that arises from the totality of the writer's experience; it cannot be imposed from outside. Fiction problems cannot be quantified and measured and tested, except as part of the whole. They are not neat. When the context and form are imposed from the outside

you end up with a romance novel or something else that can be written by number.

I don't believe we should even think about trying to teach creativity, which we don't understand anyway, but rather direct our efforts at how to teach the teachers not to fear it when it arises. We know that our society values writers and artists of all kinds so little that most of them must work at real jobs in order to eat, and do their writing and their art when they can. Why not let them teach in their fields instead of assigning the task to people who don't comprehend the process? Practicality says there are not enough of them to fill the vacuum; then let them teach the teachers.

Literature appreciation courses do not prepare anyone to teach writing, although they turn out fine critics of finished work. Art history courses will not insure that teachers understand and sympathize with the process of creating art. We should be wary of ever-more-clever tests that attempt to quantify creativity. They are measuring something, to be sure, but possibly not what they think they are measuring.

In my Utopia, cooks will teach cooking, doctors doctoring, writers writing, artists art, and little girls will be allowed to paint purple fences if they want to. In my Utopia it will be understood that reality wants a lot of testing. And no one will rush out with a hammer, board, and nails to shore up the boundary that is being pushed or even breached, least of all a teacher.

Postscript: The Play of the Mind

Sunday, August 14

. . . I always feel as if I've been gone longer than I have. It's been three weeks this time, and now the corn is high over my head, eight feet tall, nine feet . . . One of the cats is under the corn -- Pumpkin. She greets me with her hoarse Siamese-like noises, but she does not stir. It is very hot today, cool there in the deep shade. An emerald-green frog is on top of the beans in my colander. When I add more beans, it hops out, vanishes under the canopy of bean leaves. Earlier I spotted a salamander in the potatoes where the earth stays cool and moist under a deep mulch of straw. Thoughts of the new novel chase each other through my mind. A scene that isn't right yet . . . I try it from a new perspective, another viewpoint, let it play itself out in the mental theatre where all scenes are enacted over and over. Every year the ground is richer, in better condition than before; it gives me little presents now. A volunteer tomato plant is heavy with paste tomatoes. I wasn't sure what kind they would be when I first saw it, hoed around it, and let it be. In the middle of the beans there is a stray potato plant, thriving among the foreigners. Red skin? Kennebec? Netted gem? I won't know until I dig it out next month -- another surprise. I don't know the names of the characters in the new novel

yet. They talk to each other, but seldom to me, unless I trick them into it, put them in a scene where it is necessary to reveal their names. I don't use those scenes. How many such scenes, other scenes, have I played out, lived through, discarded? Living through the scene from *his* viewpoint has cleared up a problem with it, I think. Once more, from *her* viewpoint this time. If I don't try to see it too hard, I can perceive a golden shower of pollen falling straight down in the windless day, the promise of the seed fulfilled. I have my scene; it is good to be working. I tuck the new scene back among the others, content with it, and leave the garden to the salamanders, the jewel-like frogs, a sapphire dragon fly, and the golden pollen fall.